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Joint Agency Staff Report on Assembly Bill 8: 2022 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California

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ABSTRACT

The Joint Agency Staff Report on Assembly Bill 8: 2022 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California is in accordance with Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013), which requires the California Energy Commission (CEC) and California Air Resources Board (CARB) to "jointly review and report on progress toward establishing a hydrogen-fueling network that provides the coverage and capacity to fuel vehicles requiring hydrogen fuel that are being placed into operation in the state."

The CEC's Clean Transportation Program has invested nearly $166 million and plans to invest a total of $279 million in public hydrogen infrastructure primarily for light duty vehicles through fiscal year 2023-2024. These investments, combined with investment from the Volkswagen Mitigation Trust Fund and the private sector, are expected to support 200 hydrogen refueling stations. As of November 11, 2022, 62 stations have opened for retail sales, with the remaining stations scheduled to open by 2027.

There were 12,169 light duty fuel cell electric vehicles (FCEVs) on the road as of September 2022, and the 62 open retail stations can serve as many as 51,000 FCEVs when operating at capacity – about four times the fueling needs of the current on-road fleet. However, customer experience is undermined by a variety of factors, including station downtime, hydrogen supply disruptions, and other factors.

The CEC estimates the network of 200 stations will have the capacity to serve nearly 274,000 light-duty FCEVs. At least 13 of these stations will have the capability to serve medium- or heavy-duty vehicles. Planned station development should be sufficient to enable growing FCEV sales beyond auto manufacturers' projections in the near term. CEC and CARB staffs intend to continue evaluating the FCEV market as it evolves.

Keywords: Assembly Bill 8, California Air Resources Board, California Energy Commission, Clean Transportation Program, fuel cell electric vehicle, hydrogen refueling station

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EXECUTIVE SUMMARY

The *Joint Agency Staff Report on Assembly Bill 8: 2022 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California* (2022 Joint Report) describes the investment, planning, development, and use of hydrogen refueling stations to support fuel cell electric vehicles (FCEVs) in California as directed by Assembly Bill (AB) 8 (Perea, Chapter 401, Statutes of 2013). AB 8 further directs the California Energy Commission (CEC) to allocate $20 million annually, not to exceed 20 percent of the funds appropriated by the Legislature, from the Clean Transportation Program toward public hydrogen refueling stations until there are at least 100 publicly available stations in California. Governor Edmund G. Brown Jr.'s Executive Order B-48-18 set a goal of 200 hydrogen refueling stations by 2025.

Governor Gavin Newsom's Executive Order N-79-20 sets goals for all new passenger cars and trucks sold in California to be zero-emission by 2035, all medium- and heavy-duty trucks and buses operated in California to be zero-emission by 2045 everywhere feasible, and all drayage trucks to be zero-emission by 2035. The goals will influence the policies, requirements, and investments planned by numerous California agencies and municipalities, including the CEC and California Air Resources Board (CARB).

With the Clean Transportation Program allocating funding to 168 stations (including 16 stations included in a CEC agreement funded fully by match share) and the private sector announcing an additional 7 privately funded stations, the state expects at least 175 stations to be open retail by 2027. In addition, the CEC released a grant funding opportunity, GFO-22-607, on October 21, 2022, using $27 million of general funds for zero-emission vehicle infrastructure in the 2021 Budget Act per Senate Bill 170 (Skinner, Chapter 240, Statutes of 2021) with the objective of reaching the 200-station goal by 2027.

When all 175 stations are open, the network will be capable of supporting nearly 238,000 light-duty FCEVs when operating at 100 percent availability. The CEC estimates that once 200 stations are open in the state, nearly 274,000 FCEVs can be supported, assuming the remaining 25 stations have a capacity of 1,000 kilograms of hydrogen per day (kg/day) per station. These numbers are revised downward from last year's joint report because of trends observed in station developers' station capacity plans. Despite the lower capacity numbers, the state is expected to have more nameplate fueling capacity than the projected light-duty FCEV need for the foreseeable future, which provides opportunity for auto manufacturers to accelerate the planned deployment of FCEVs in California over the coming

KEY TAKEAWAYS

California is meeting the AB 8 100-station goal with expended and committed funds (a combination of public and private funding) supporting 175 stations, and California is committed to meeting the 200-station goal.

California has 62 open retail stations.

Cumulative sales or leases of light-duty FCEVs in California have been 13,998, while 12,169 FCEVs are estimated to be on California's roads as of the end of the third quarter of 2022.

Cumulative investment in hydrogen refueling infrastructure by California and lead countries through 2021 totals nearly $1.3 billion.

The COVID-19 pandemic continues to affect station development.

years. Furthermore, actual network fueling capacity depends on the reliability of hydrogen supply and station uptime, and improving this reliability is key to providing all stakeholders, most notably FCEV drivers and auto manufacturers, confidence in the FCEV market such that it can grow to its full potential.

The CEC and CARB also evaluate fueling needs regionally to analyze if the specific areas where vehicles are being sold and leased are adequately served by stations. This analysis is particularly important during early market development, as having infrastructure in places where potential customers need them can influence the decision to adopt FCEV technology. The largest urban areas of the state will experience network capacity increases capable of supporting tens of thousands more FCEVs within the next two years. Other urban areas will need stations to open these markets to FCEVs. The state is endeavoring to do better in providing benefits to disadvantaged communities. About 62 percent of California's residents who live in disadvantaged communities are within a 15-minute drive time of an open retail or planned hydrogen station. However, rural disadvantaged communities and disadvantaged communities with lower population density are not within a 15-minute driving distance to any hydrogen refueling station.

According to CEC analysis of California Department of Motor Vehicles data on the Zero Emission Vehicle (ZEV) Dashboard (Zero Emission Vehicle and Infrastructure Statistics, https://www.energy.ca.gov/data-reports/energy-insights/zero-emission-vehicle-and-charger-statistics), cumulative sales or leases of light-duty FCEVs in California have been 13,998, while 12,169 FCEVs are estimated to be on California's roads as of the end of the third quarter of 2022. CARB reported, in the *2022 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development*, that the FCEV population in California could grow to 34,500 FCEVs by 2025 and 65,600 FCEVs by 2028. CARB bases these projections on the latest auto manufacturer survey responses. Actual FCEV sales have historically been lower than auto manufacturer projections.

The 2028 projected FCEV population of 65,600 is less than a quarter of the 274,000 FCEVs that the anticipated fueling network of 200 stations could support based on the nameplate capacity of the stations, assuming future remaining stations will each have an average of 1,000 kg/day capacity. Even with the assumption that stations would dispense no more than 80 percent of nameplate capacity in real-world operating conditions, auto manufacturers could still nearly triple FCEV deployment plans for 2028. The CEC implemented a multiyear funding strategy in the last grant funding opportunity, GFO-19-602, to enable station equipment cost savings and continuous hydrogen refueling station development. With this focus on improving the regularity of station network growth, the state is working to create stability and confidence in the FCEV market to enable auto manufacturer FCEV deployment projections to accelerate. The maturation of hydrogen equipment and distribution supply chains is important for building this stability and confidence, as well.

In addition to light-duty FCEVs, the state is working to support the demonstration and deployment of medium- and heavy-duty FCEVs. At least 13 of the 175 projected stations should be capable of fueling medium- or heavy-duty vehicles in addition to light-duty ones, thereby leveraging infrastructure to address multiple markets and accelerating the development of commercial fuel cell electric trucks. According to the CEC ZEV Dashboard where vehicle and infrastructure statistics are compiled at https://www.energy.ca.gov/zevstats, there were 61 medium- and heavy-duty FCEVs (all buses) registered in the state as of June 2022.

The ongoing investments in medium- and heavy-duty FCEVs and infrastructure for drayage trucks and transit vehicles will expand with funding from the 2022 Budget Act. The CEC has also invested in medium- and heavy-duty hydrogen infrastructure by funding projects for nearly $40 million total in grant funds. This CEC investment in medium- and heavy-duty infrastructure will yield a daily fueling capacity of about 8,700 kg., based on the nameplate capacity of the projects. In addition, in early 2022, the CEC launched EnergIIZE, California's first-ever block grant program designed to provide streamlined incentives for fueling infrastructure for zero-emission commercial vehicles. EnergIIZE includes a funding lane specifically for hydrogen refueling infrastructure.

Since the last year's joint report, 10 hydrogen refueling stations opened, bringing the total number of open retail stations developed in California to 62, as of November 11, 2022. This network of open retail stations includes seven stations that are considered temporarily non-operational. The TNO stations previously achieved open retail status but have been unavailable for customer fueling for a period greater than 30 days for various reasons, including the time needed for mechanical upgrades or repairs, station testing, and reviews by local officials. These TNO stations are expected to become available for customer fueling again in the future; in fact, one station previously designated as TNO has become available for customer fueling this year. The remaining 55 open retail stations are available for customer fueling with the exception of downtime events that can last for periods up to 30 consecutive days due to supply issues or maintenance.

These open retail stations have the capacity to support nearly 51,000 light-duty FCEVs. The average daily dispensing level across the network recovered in 2021 to near prepandemic levels and continued to grow to above the prepandemic level at 7,000 kg/day in the second quarter of 2022. Station development times were decreasing until the COVID-19 pandemic slowed many station development activities. The COVID-19 pandemic continues to affect station development in the forms of global inflation, labor and material shortages, and supply chain interruptions. CEC staff is learning more about these issues from station developers and plans to incorporate feedback from workshops in future solicitations.

As directed in AB 8, the CEC has allocated $20 million per year or 20 percent of the total Clean Transportation Program Investment Plan allocation each year for light-duty public hydrogen stations and plans to continue allocating funding through Fiscal Year 2023–2024. The Clean Transportation Program investment in hydrogen refueling stations thus far is about $166 million, and the Clean Transportation Program investment in hydrogen refueling stations will total nearly $279 million by the current end date of the AB 8 program funds, which is January 1, 2024. In addition, the 2022 Budget Act allocates an additional $60 million to expand hydrogen refueling infrastructure for three fiscal years starting in 2023.

The private sector has contributed through match funding to station development, as well as their independent investments in hydrogen refueling stations and production plants that are outside CEC agreements. As of November 11, 2022, grant recipients contributed nearly $92 million in match funding and will contribute another $99 million by the end term of the CEC grant agreements funded under GFO-19-602. These contributions will bring the total public and private investment in hydrogen refueling stations under the Clean Transportation Program to nearly $470 million.

The CEC will continue to make investments to reach the 200-station goal while working to address barriers to large-scale commercialization and deployment of FCEVs, such as station unreliability that diminishes consumer confidence in FCEVs. Another barrier is inconsistency in the supply of hydrogen. The 2022 Budget Act provides $100 million to the CEC to distribute grants for producing hydrogen in-state that through electrolysis or biofuels using renewable energy, which in addition to private investments, should help improve supply consistency.

As in last year's joint report, CEC staff reached out to stakeholders with knowledge about FCEV and hydrogen refueling infrastructure deployment in China, Germany, Japan, and South Korea. All these countries have increased the numbers of hydrogen refueling stations and FCEVs since last year. Based on the numbers CEC staff obtained from these stakeholders in June and July 2022, South Korea has the most open stations at 172, followed by Japan with 159, China with 147, Germany with 96, and California with 62. On a per capita basis, California ranks second after South Korea for hydrogen stations. South Korea also leads in the number of registered light-duty FCEVs with 20,621 vehicles deployed. California is second with 12,169, and Germany has 1,399. Japan reports 7,232 light-duty FCEVs and 120 city buses and small trucks but did not specify if the numbers were registered vehicles or cumulative sales, which may overestimate the actual on-road population due to potential vehicle retirements. China leads commercial FCEV deployment with 8,941 vehicles, although it did not specify whether the number was registered vehicles or cumulative sales. South Korea reports having 157 buses and trucks registered, Germany reports 107 medium- and heavy-duty vehicles registered, and California has 61 registered fuel cell buses. On a per capita basis, California ranks second after South Korea in terms of total FCEV deployments.

The cumulative government investments through 2021 in hydrogen refueling infrastructure in California, Germany, Japan, and South Korea totals nearly $1.3 billion. This total includes $740 million for Japan, $257 million for South Korea, $166 million for California, and $119 million for Germany. On a per capita basis, California ranks third after Japan and South Korea in terms of government funding for public hydrogen refueling stations. These countries have committed to investing more in 2022 with goals to expand their refueling station networks. Funding updates for China were not available.

California is providing the refueling infrastructure support necessary to accommodate the FCEVs that auto manufacturers are bringing to market in the state. Despite barriers related to infrastructure reliability, hydrogen supply, and other factors, the capacity of the existing and projected hydrogen refueling station network exceeds current and projected vehicle demand at least through 2028. The deployment of refueling infrastructure and FCEVs must accelerate to enable the scale of FCEV sales needed to make a mature market. CEC and CARB staffs intend to continue jointly evaluating the FCEV market to inform potential future funding decisions. This evaluation shall include examining opportunities and trends in different transportation market segments and potential use of hydrogen in broader energy system decarbonization.

CHAPTER 1: Introduction

Assembly Bill (AB) 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program.[1] Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorized the Clean Transportation Program until January 1, 2024, and directed the California Energy Commission (CEC) to allocate $20 million annually, not to exceed 20 percent of the amount of funds appropriated by the Legislature, toward at least 100 publicly available hydrogen refueling stations.[2]

AB 8 requires annual review and reporting by the CEC and California Air Resources Board (CARB). The *Joint Agency Staff Report on Assembly Bill 8: 2022 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California* (2022 Joint Report) is the seventh such annual report. CARB published the *2022 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network* (2022 Annual Evaluation) on September 19, 2022, also required by AB 8.[3] Appendix C lists references for previous reports.

This report will review progress toward establishing a hydrogen refueling network that provides the coverage and capacity to support fuel cell electric vehicles (FCEVs) requiring hydrogen fuel that are being placed into operation in the state. The report will also assess whether funding from the Clean Transportation Program remains necessary to achieve the 100-station goal per AB 8.[4] This report is organized with five analytical chapters to cover what is required in AB 8:

- Chapter 2: The Coverage and Capacity of the Hydrogen Refueling Station Network
- Chapter 3: Fuel Cell Electric Vehicle Deployment
- Chapter 4: Time Required to Permit and Construct Hydrogen Refueling Stations
- Chapter 5: Amount and Timing of the Growth of the Hydrogen Refueling Network
- Chapter 6: Remaining Cost and Time Required to Establish a Network of 100 and 200 Hydrogen Refueling Stations

Governor Edmund G. Brown Jr.'s Executive Order B-16-12 directed state agencies to promote the rapid commercialization of zero-emission vehicles (ZEVs) and set a target of 1.5 million ZEVs in California by 2025.[5] Governor Brown's Executive Order B-48-18 established goals of achieving 200

1 California Legislative Information. Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200720080AB118.

2 California Legislative Information. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB8.

3 California Air Resources Board. September 2022. *2022 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development*. https://ww2.arb.ca.gov/sites/default/files/2022-09/AB-8-Report-2022-Final.pdf.

4 California Legislative Information. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB8.

5 Office of Governor Edmund G. Brown Jr. Executive Order B-16-2012. https://www.ca.gov/archive/gov39/2012/03/23/news17472/index.html.

hydrogen stations by 2025 and 5 million ZEVs in California by 2030.[6] On September 23, 2020, Governor Gavin Newsom's Executive Order N-79-20 set goals that all new passenger cars and trucks sold in California be ZEVs by 2035, all medium- and heavy-duty trucks and buses operated in California be ZEVs by 2045 everywhere feasible, and all drayage trucks be ZEVs by 2035.[7] All three imperatives strengthen California's focus and activities for hydrogen refueling infrastructure and ZEVs. CARB has been working to implement these executive order goals, and on August 25, 2022, the Board approved the Advanced Clean Cars II regulation package that requires all new cars and light-duty trucks sold in California to be ZEVs, including plug-in hybrid electric vehicles, by 2035.[8] The effective date of the regulation is November 30, 2022.

The CEC Fuels and Transportation Division and CARB program staffs collaborate with many experts to plan and encourage development of hydrogen refueling infrastructure and deployment of fuel cell electric vehicles, including:

- The Governor's Office of Business and Economic Development (GO-Biz) and the California Department of Food and Agriculture, Division of Measurement Standards (CDFA/DMS).
- The South Coast Air Quality Management District (SCAQMD), Bay Area Air Quality Management District (BAAQMD), and other air districts.
- Local agencies, including planning, building, and safety officials.
- The United States Department of Energy (U.S. DOE) and national laboratories, including the National Renewable Energy Laboratory (NREL) and Pacific Northwest National Laboratory (PNNL).
- Industry stakeholders, including the Center for Hydrogen Safety under the auspices of the American Institute of Chemical Engineers (AiCHe), Hydrogen Fuel Cell Partnership, California Hydrogen Business Council, SAE International, and the CSA Group.

Staff also consider input from public comments received in workshops and submitted to the docket to develop grant solicitations and analyses. The public is encouraged to visit the following web pages to become involved in CEC activities:

- Subscriptions: https://www.energy.ca.gov/subscriptions
- Events: https://www.energy.ca.gov/events
- Solicitations: https://www.energy.ca.gov/funding-opportunities/solicitations

CEC and CARB staffs review the year's refueling trends and describe other hydrogen and fuel cell projects that are expanding the potential for FCEVs, including buses and trucks, to serve multiple

6 Office of Governor Edmund G. Brown Jr. Executive Order B-48-18. https://www.ca.gov/archive/gov39/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/index.html. The Governor's Interagency Working Group on ZEVs released a *2018 ZEV Action Plan Priorities Update* in response to the executive order. http://business.ca.gov/Portals/0/ZEV/2018-ZEV-Action-Plan-Priorities-Update.pdf.

7 Office of Governor Gavin Newsom. Executive Order N-79-20. https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf.

8 California Air Resources Board. August 25, 2022. "California Moves to Accelerate to 100% New Zero-Emission Vehicle Sales by 2035." https://ww2.arb.ca.gov/news/california-moves-accelerate-100-new-zero-emission-vehicle-sales-2035.

functions in transitioning to a national and international zero-emission transportation system. The data this joint report uses, unless otherwise noted, are:

- From the third quarter of 2021 through the second quarter of 2022 for hydrogen refueling station related analyses.
- Through the end of the third quarter of 2022 for the latest number of fuel cell electric vehicles.
- As of November 11, 2022, for reporting new station openings.

CHAPTER 2: The Coverage and Capacity of the Hydrogen Refueling Station Network

This chapter discusses the progress toward establishing a hydrogen refueling network to provide the coverage (the placement of stations) and capacity (how many FCEVs stations and the network can support) needed to fuel FCEVs that are on the road in California. The chapter also discusses station statistics such as hydrogen dispensed, utilization, retail price of hydrogen, station availability, and hydrogen supply to analyze how the current network of stations is sufficient to serve on-road FCEVs. The chapter also touches on hydrogen infrastructure for medium- and heavy-duty vehicles.

The coverage and capacity of the hydrogen refueling station network continue to grow in California. The available fueling capacity of open retail stations is nearly quadruple the estimated fuel demand from current on-road FCEVs. The estimated nameplate fueling capacity of the planned network of 175 refueling stations is more than triple the fueling needs of the projected FCEV population in 2028 according to the 2022 Annual Evaluation. The state goal of 200 stations should be met by 2027, but because the exact number of stations and their capacities that will result from GFO-22-607 are unknown, this report uses the 175-station network for evaluating coverage and capacity.

Despite the nameplate capacity of the open retail network outpacing FCEV deployment, hydrogen supply shortages and station downtime have limited actual fueling capacity at times. Reliability must be improved to achieve the capacity of which the stations are capable and increase driver confidence in fuel availability.

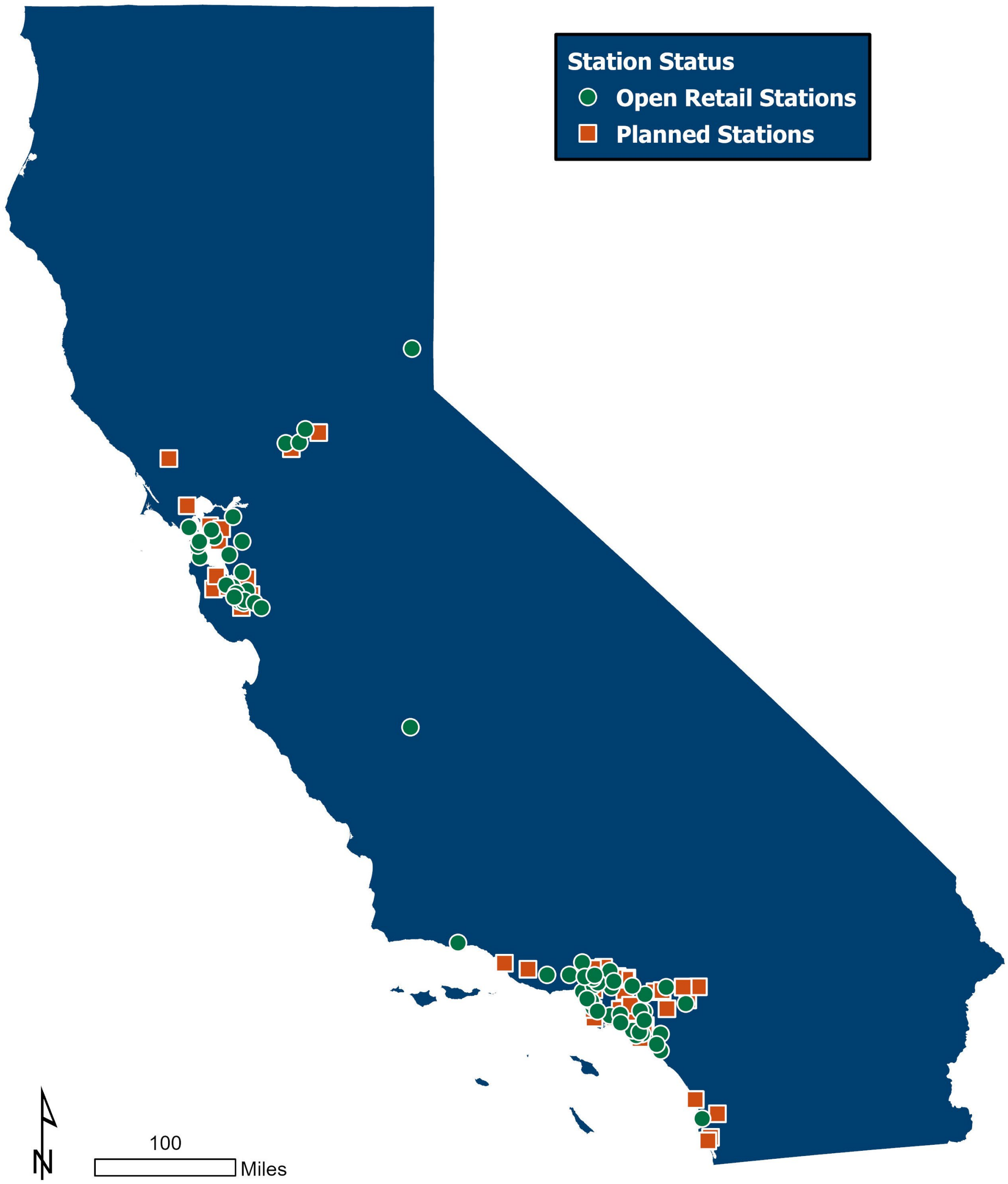
Figures 1 through 3 show the locations of stations in the hydrogen refueling station network in California. Many of the stations proposed for future batches of the CEC's funding solicitation, GFO-19-602, do not have locations yet and are not shown in these figures. The California network includes 62 open retail stations, 31 planned stations, and 82 stations that are part of the future batches of GFO-19-602. Appendix A lists 106 stations with addresses. Appendix B lists the changes in the station network from 2017 to 2022.

The network of open retail stations includes 62 stations; 55 of these stations are available for customer fueling with the exception of brief downtime events, and 7 stations are considered temporarily non-operational (TNO),[9] as they have previously achieved open retail status but have been unavailable for customer fueling for a period greater than 30 days for various reasons. These TNO stations are expected to become available for customer fueling again in the future and are shown as open retail stations in Figures 1 through 3.

9 The 2021 Joint Report stated there were four TNO stations. Since then, one station reopened but four stations became TNO, bringing the total to seven. A TNO station in Riverside is available for FCEV drivers to fuel by reservation.

Overall, the current 62 open retail stations have the capacity to support nearly 51,000 FCEVs,[10] which is nearly quadruple the estimated 12,169 FCEVs on the road as of the third quarter of 2022.[11]

Figure 1: Hydrogen Refueling Station Locations in California



Source: CEC

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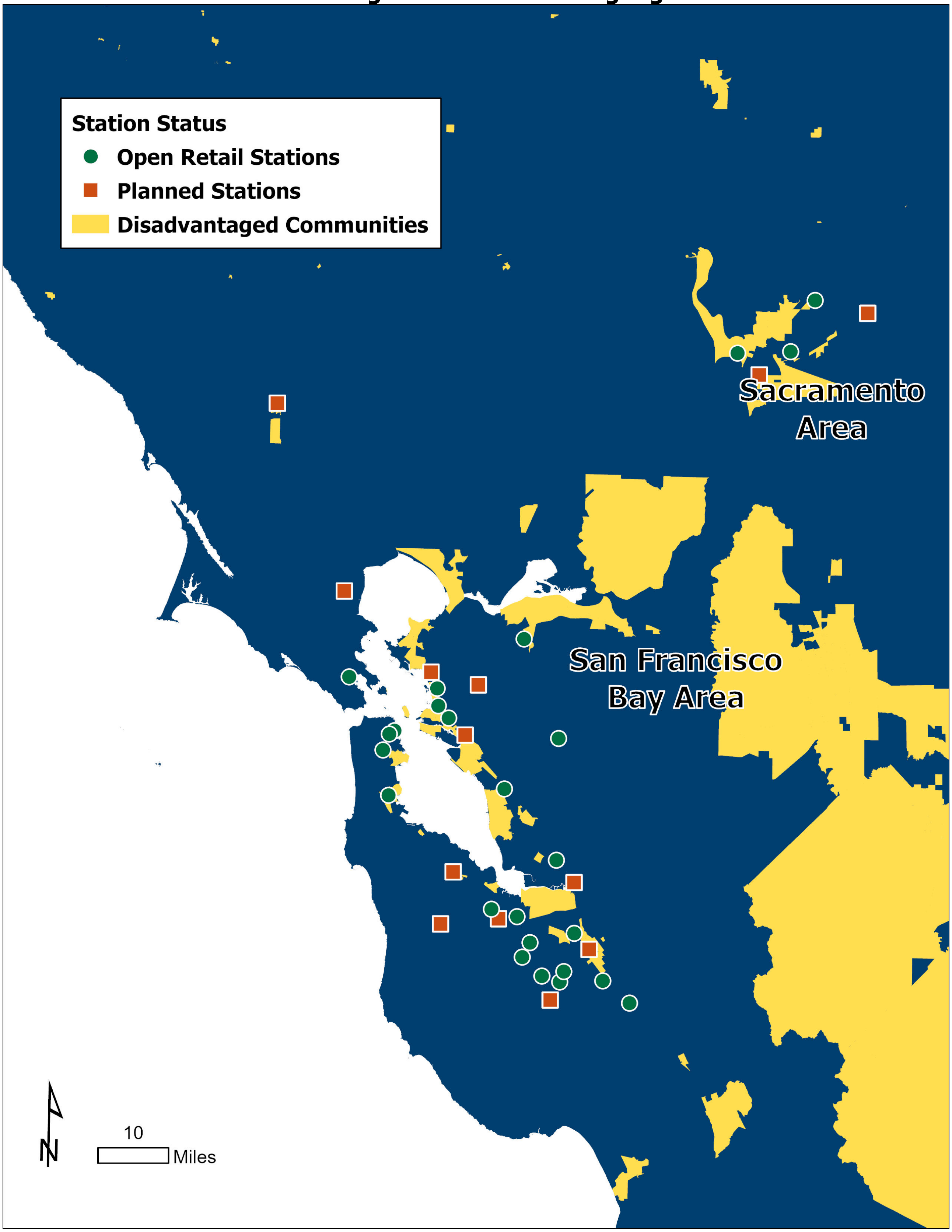
10 CEC staff assumed 0.7 kilograms as the average amount of hydrogen used per FCEV daily.

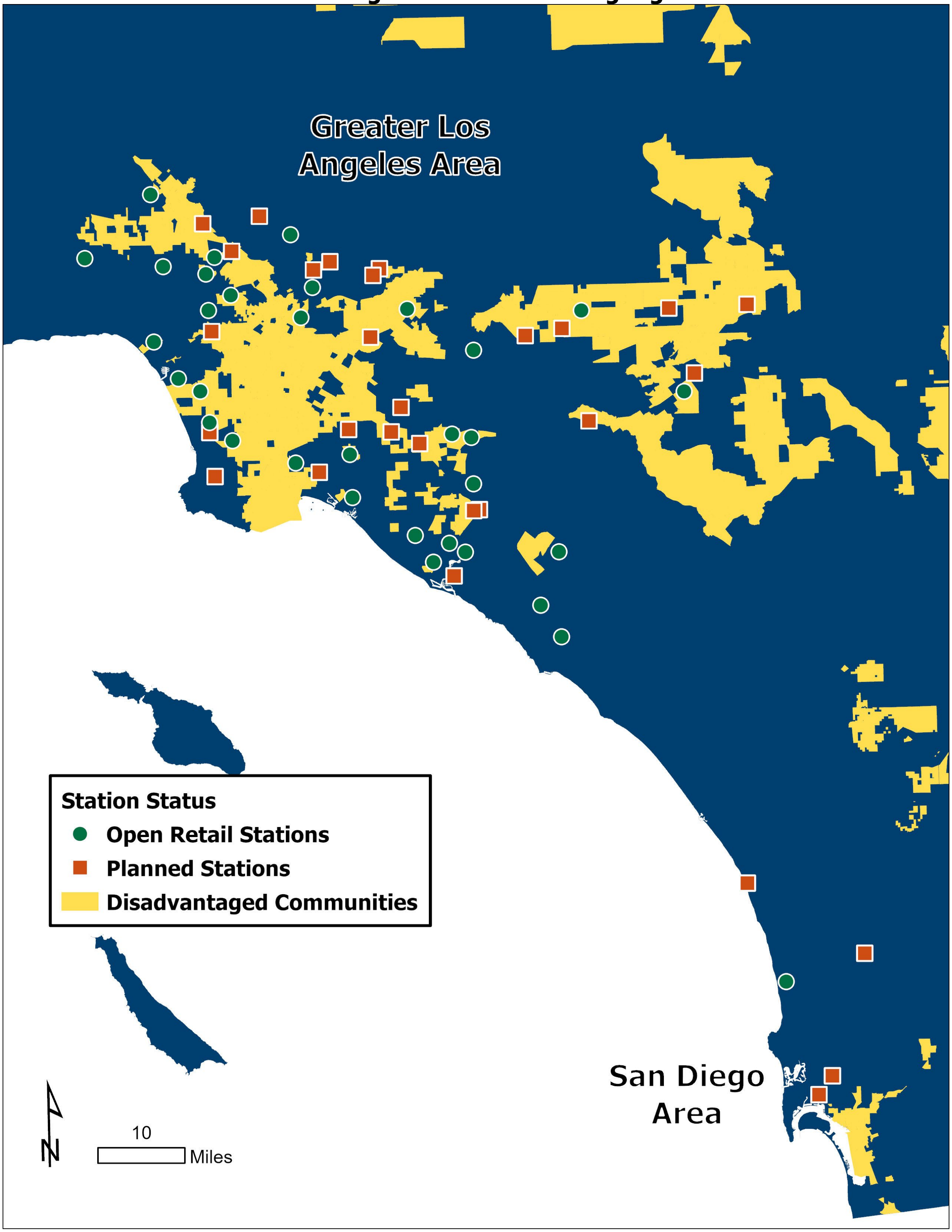
11 The on-road FCEV number is estimated by adding the 2021 DMV on-road vehicle data and the cumulative sales and leases from the first quarter of 2022 through the third quarter of 2022.

Figure 2: Hydrogen Refueling Station Locations in Northern California With Disadvantaged Communities Highlighted



Source: CEC

Figure 3: Hydrogen Refueling Station Locations in Southern California With Disadvantaged Communities Highlighted



Source: CEC

The CEC continues to emphasize the importance of serving disadvantaged communities in its solicitations. With all the stations with known addresses under GFO-19-602 and privately funded stations that are proposed for development, 28 stations will be in disadvantaged communities.[12] These stations will provide coverage so that 62 percent of the disadvantaged community population and 59 percent of the general population of California will be within a 15-minute driving distance to a hydrogen refueling station. These numbers could increase as addresses for stations in future batches funded under GFO-19-602 are announced. However, as CARB noted in its 2022 Annual Evaluation, most of the rural disadvantaged communities and disadvantaged communities with lower population density are not within a 15-minunte driving distance to any hydrogen refueling station because stations are concentrated in the San Francisco Bay Area, Sacramento Area, Greater Los Angeles Area, and San Diego Area. CEC and CARB will continue to promote equity in their investments and explore options to expand hydrogen refueling network benefits to as many disadvantaged communities as possible. For example, the newly released solicitation, GFO-22-607, promotes disadvantaged communities with low access to a hydrogen refueling station as eligible areas to site new hydrogen refueling station projects.

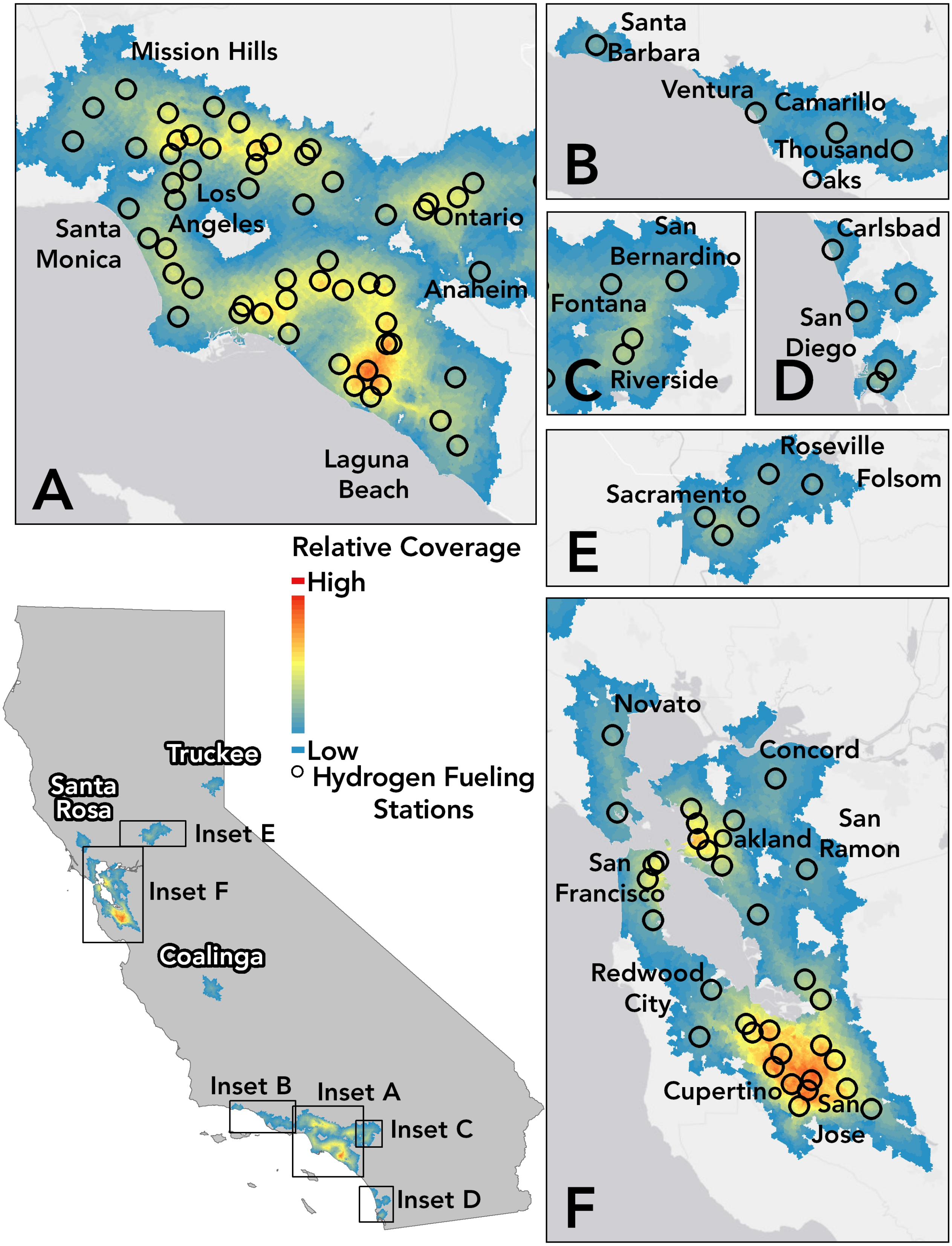
Coverage Map Using California Hydrogen Infrastructure Tool

Figure 4 displays the coverage provided by all stations in the 175-station network with known addresses. As awarded station developers notify the CEC of addresses for additional locations, or possible station relocations and other changes, the evaluation of coverage is expected to change. The figure was produced by the CARB California Hydrogen Infrastructure Tool (CHIT).[13] Areas on the map without color are not within a 15-minute drive from any hydrogen refueling station. In the coverage map, the areas shown with the red shading have the highest degree of coverage. These areas often have several stations providing coverage to neighborhoods and communities in the nearby area. The blue areas have less fueling coverage; these areas typically have a small number of available stations or are farther away from the fueling station network.

12 Disadvantaged communities are identified using the California Office of Environmental Health Hazard Assessment's CalEnviroScreen 4.0. Information is available at OEHHA, CalEnviroScreen. https://oehha.ca.gov/calenviroscreen.

13 California Air Resources Board. "Hydrogen Refueling Infrastructure Assessments." https://ww2.arb.ca.gov/resources/documents/california-hydrogen-infrastructure-tool-chit.

Figure 4: Coverage Map



Source: CARB

Quantity of FCEVs Supported by Hydrogen Refueling Station Network

Table 1 summarizes the coverage and capacity of the hydrogen refueling station network in California by showing the station quantity and fueling capacity in terms of the quantity of FCEVs that the network can support assuming a typical FCEV uses 0.7 kilograms of hydrogen daily.[14] This network summary includes both the Clean Transportation Program-funded and privately funded stations. As awardees complete the milestones specified in GFO-19-602, subject to future Clean Transportation Program appropriations and Investment Plan allocations, they may develop more stations (as shown as GFO-19-602 Future Batches in Table 1). Including all currently known publicly and privately funded stations, the projected network will contain 175 stations. The CEC released a new grant funding opportunity, GFO-22-607, on October 21, 2022, enabled by the addition of general funds for zero-emission vehicle infrastructure in the 2021 Budget Act, with the objective to reach the 200-station goal of Governor Edmund G. Brown Jr.'s Executive Order B-48-18.

These 175 currently known stations will have the capacity to support nearly 238,000 FCEVs, and the projected 200 stations will have the capacity to support more than 274,000 FCEVs, assuming future remaining stations will each have an average of 1,000 kg/day capacity. These numbers are revised downward from last year's joint report because of trends observed in station developers' station capacity plans.

In practice, the number of FCEVs supported depends on the reliability of the hydrogen supply and station equipment. Station reliability is discussed in Chapter 3. Other factors that influence the quantity of FCEVs that can be supported include the interdependency of the actual FCEV geographical distribution relative to stations, driver habits, vehicle miles traveled, and routes traveled. The number of connector stations and destination stations can affect these factors, and a future solicitation may cover more of these stations.

Table 1: Hydrogen Refueling Station Network and Quantity of FCEVs Supported

Station Status	Station Quantity	FCEVs Stations Can Support
Open Retail	62	51,000
Planned	31	52,000
GFO-19-602 Future Batches	82	135,000
Total Funded	***175***	***238,000***
Estimated Gap to 200	25	36,000
Estimated Total	***200***	***274,000***

Source: CEC

14 Pratt, Joseph, Danny Terlip, Chris Ainscough, Jennifer Kurtz, and Amgad Elgowainy. 2015. H2FIRST Reference Station Design Task, Project Deliverable 2-2. National Renewable Energy Laboratory and Sandia National Laboratories. https://www.osti.gov/biblio/1215215.

Hydrogen Dispensing and Station Utilization

The COVID-19 pandemic affected the level of hydrogen dispensing statewide, particularly in 2020. During 2021 and through the second quarter of 2022, average daily station dispensing continued to recover. By the second quarter of 2022, peak hydrogen dispensing has even increased by 90 percent above the prepandemic peak of late 2019.

Factors affecting the number of kilograms dispensed across the network may include fluctuations in commuting and daily driving, extended time frames for planned and unscheduled maintenance at the stations, and the availability of delivered hydrogen. The existing network of hydrogen refueling stations in California has ample fueling capacity to support the on-road light-duty FCEVs, with the average utilization[15] of the overall network now just above 20 percent.

The CEC requires grant recipients to report hydrogen dispensing data. Once an agreement term ends, some operators continue reporting data voluntarily. Figure 5 shows the average daily hydrogen dispensing in California based on the operators' reports. For stations that do not report, staff estimated the average daily dispensing based on the daily regional dispensing (Greater Los Angeles Area, San Francisco Bay Area, San Diego Area, Sacramento Area, and Connector Area outside the four other areas) where each nonreporting station is located. California has 62 open retail hydrogen refueling stations. CEC staff received data from 49 stations and estimated dispensing for 11 stations in the second quarter of 2022. This figure does not include 2 of 62 open retail stations because they became open retail after the second quarter of 2022.

The average weekly dispensed fuel, shown in solid color in Figure 5,[16] is reported by station operators. The patterned area shows the estimated dispensing for stations that do not report to the CEC. Above each quarter, the quarterly average daily dispensing is shown. In 2019, many agreements ended, and many of those stations discontinued reporting fueling data to the CEC; hence, the patterned line is larger in that year. Since then, many station developers have agreed to provide the CEC with an abbreviated amount of fueling data to allow the CEC to do this reporting. Figure 5 shows that in the second quarter of 2022, average daily dispensing has increased to about 7,000 kg/day, about 90 percent over the pre-COVID-19 daily average of 3,700 kg/day. Staff assumes this increase is due to the increase in FCEV population and more people driving their FCEVs as the state has reopened its economy. Figure 6 shows the percentage of hydrogen dispensed (actual and estimated) in each region from the beginning of the third quarter of 2021 to the end of the second quarter of 2022. About two-thirds of all hydrogen dispensed in California is in the Greater Los Angeles Area.

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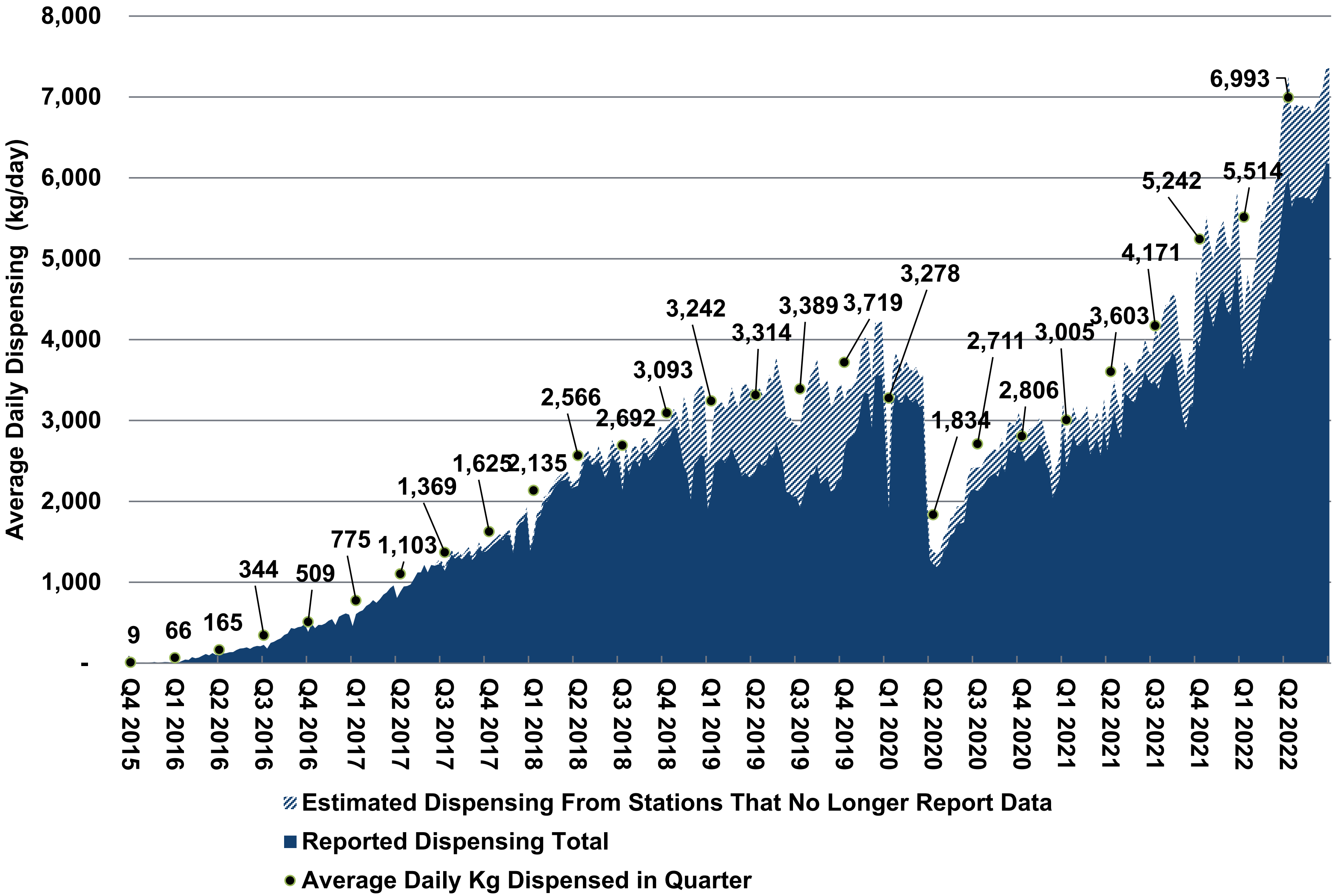
15 The term "utilization" is used in this joint report to align with the industry norm to describe the ratio of fuel throughput to the nameplate capacity of the station or the network of stations.

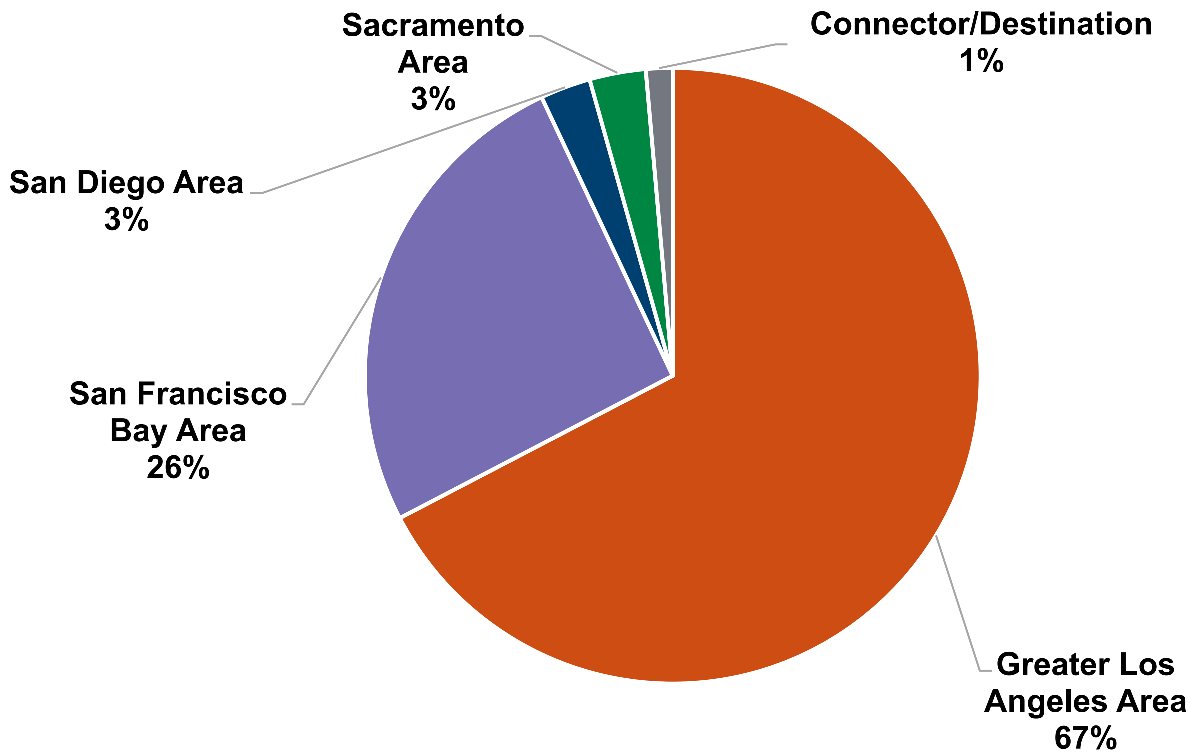
16 Estimated dispensing fluctuates since reporting requirements vary according to CEC agreements.

Figure 5: Average Daily Hydrogen Dispensing



Source: CEC

Figure 6: Percentage of Hydrogen Dispensing by Region (Q3 2021 – Q2 2022)

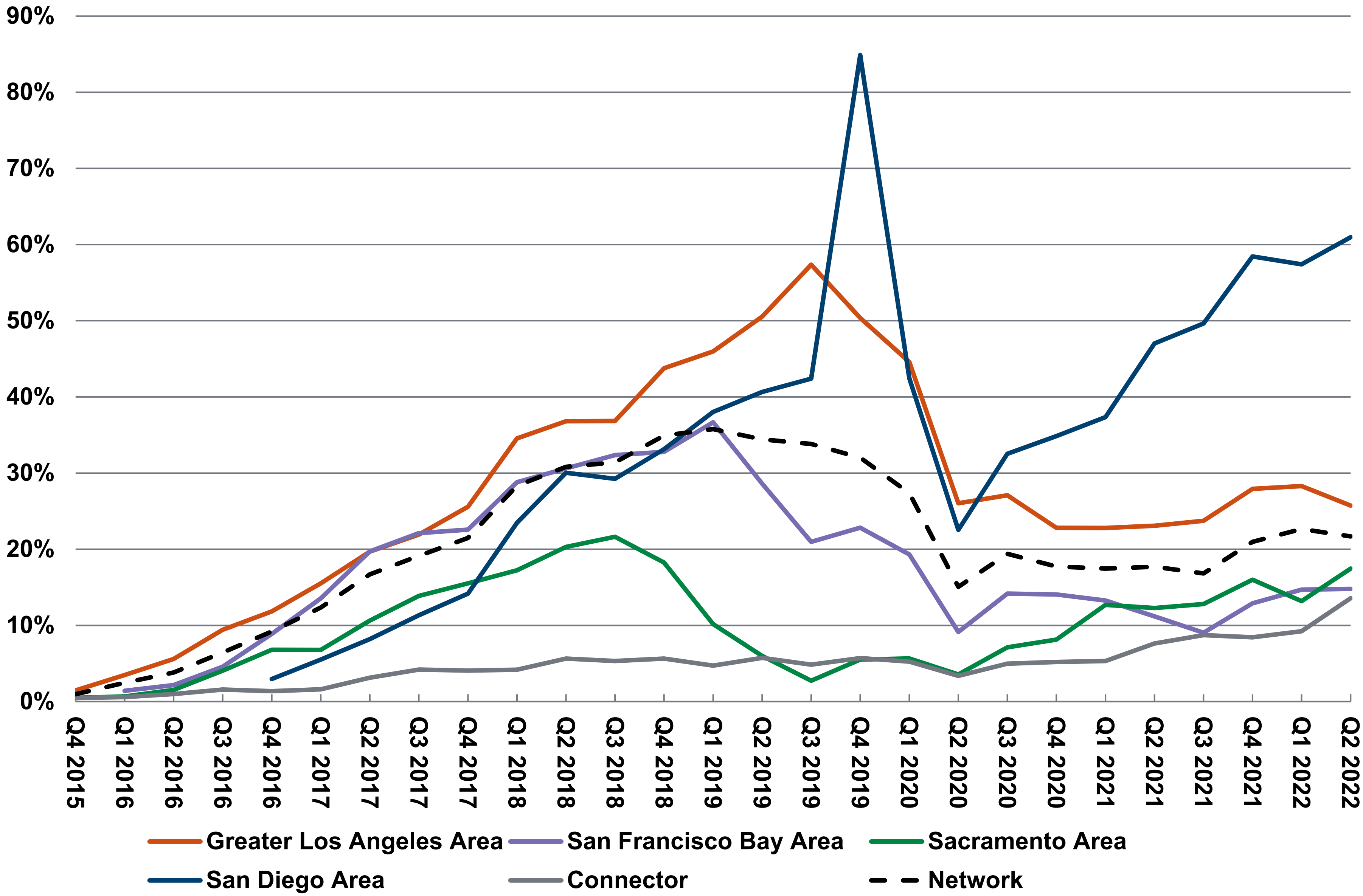


Source: CEC

Figure 7 shows the quarterly hydrogen station utilization rates statewide. The overall network utilization was 22 percent in the second quarter of 2022. The utilization percentage has been hovering around 20 percent consistently since the first quarter of 2020 because fueling capacity and fueling demand have grown at a similar rate. In other words, as more stations open and add capacity to the network of hydrogen stations, FCEV sales and leases are increasing at a similar rate.

The San Diego Area is the area with the highest average utilization rate, more than 60 percent. This area has only one hydrogen refueling station and has been the area of greatest need for additional stations. Several more stations are nearing completion and should alleviate the heavy burden that the one station is carrying. The Greater Los Angeles Area is the region with the next highest average utilization rate, near 30 percent.

Figure 7: Hydrogen Station Utilization by Quarter



Source: CEC

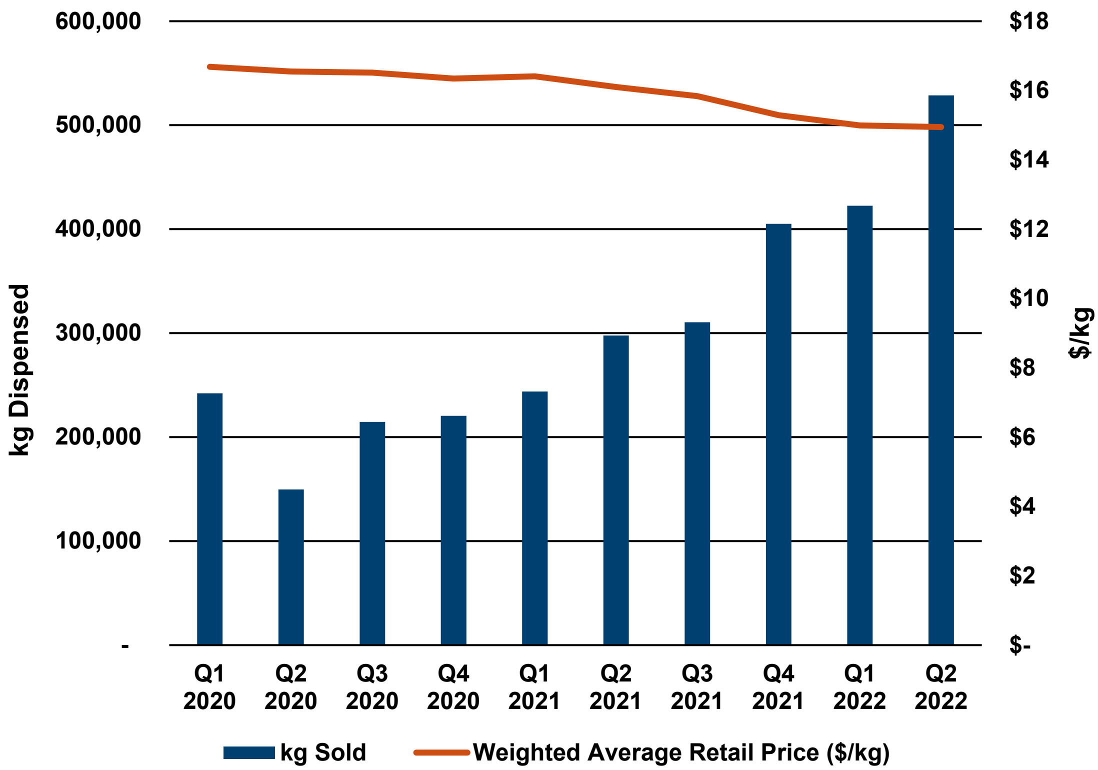
Retail Price of Hydrogen

Figure 8 shows the weighted average retail price of hydrogen and the total kilograms of hydrogen sold per quarter for hydrogen stations that report dispensing data to the CEC. This sample represents all stations that currently have agreements with the CEC and are required to report their fueling data and stations that voluntarily submit their data to the CEC. This accounts for about 70 percent of open retail stations in the state from the first quarter of 2020 to the second quarter of 2022.

Figure 8 shows that the average price of dispensed hydrogen decreased from $16.68 per kilogram in the first quarter of 2020 to $14.95 per kilogram in the second quarter of 2022. As of July 8, 2022, about half of the open retail stations in California have increased the hydrogen fuel price at the pump to nearly $19 per kilogram, tax included. In addition, as of November 1, 2022, five stations have increased the hydrogen fuel price at the pump to nearly $25 per kilogram. FCEVs are about 2.5 times more efficient than gasoline-powered vehicles.[17] Therefore, in terms of driving range obtained from the fuel, $19 per kilogram of hydrogen is equivalent to paying about $7.60 for a gallon of gasoline, and $25 per kilogram of hydrogen is equivalent to paying about $10.00 for a gallon of gasoline. These increases are not reflected in Figure 8 because the analysis includes data only through the second quarter of 2022. Station developers have cited that the recent price increases are due to increasing energy costs. There has also been a recent price reduction in CARB Low Carbon Fuel Standard (LCFS) credits, meaning station operators are earning fewer dollars per credit. LCFS revenue can help subsidize the cost of hydrogen to customers.

17 California Air Resources Board. 2020. "Unofficial electronic version of the Low Carbon Fuel Standard Regulation." https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf.

Figure 8: Weighted Average Price of Hydrogen and Total Kilograms Sold Per Quarter



Source: CEC

Hydrogen Dispensed

Most of the hydrogen dispensed in the California station network is produced using natural gas steam methane reformation (SMR) and the purchase of biogas credits to receive CARB LCFS credits.

The CARB LCFS Program allows program participants to meet the renewable requirements by using either direct renewable content or purchasing renewable attributes, or credits. The CARB LCFS Program defines renewable hydrogen as hydrogen derived from electrolysis of water or aqueous solutions using renewable electricity, catalytic cracking or steam methane reforming of biomethane, or thermochemical conversion of biomass, including the organic portion of municipal solid waste.[18] The LCFS Program explains how indirect accounting may be used for renewable natural gas to produce hydrogen for transportation purposes by obtaining environmental attributes.[19] Renewable electricity, for renewable hydrogen production by electrolysis, means electricity derived from sources that qualify as eligible renewable energy

18 California Code of Regulations Title 17, Division 3, Chapter 1, Subchapter 10, Article 4, Subarticle 7, §95481.

19 California Air Resources Board. July 2020. "Unofficial Electronic Version of the Low Carbon Fuel Standard Regulation." https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf.

resources as defined in California Public Utilities Code Sections 399.11–399.36.[20] These code sections define renewable electricity as electricity produced via many renewable pathways, including solar, wind, geothermal, biomass, landfill gas, municipal solid waste, tidal energy, and others.[21]

The CEC used to receive data on the kilograms of hydrogen dispensed at stations and the percentage of renewable hydrogen dispensed in attestations provided by station developers, per CEC agreements. However, many agreements have ended, so the CEC does not have a meaningful sample size to report the renewable hydrogen content. For stations reporting to the CARB LCFS Program under the hydrogen refueling infrastructure (HRI) provision, [22] the CARB 2022 Annual Evaluation shows 59 percent renewable content in 2021 (data from 51 stations) and the first quarter of 2022 (data from 50 stations), a noticeable decrease from 92 percent renewable content reported in the CARB 2021 Annual Evaluation. This reported renewable content most likely includes the purchase of biogas credits, similar to the renewable content reported to the CEC.

The CEC will continue to explore ways to help increase the renewable content of hydrogen directly produced in-state that is used in vehicles.

Hydrogen Supply

A resilient, diverse, and reliable hydrogen supply chain is vital to developing the hydrogen refueling network. The *hydrogen supply chain* refers to the production of hydrogen molecules and the delivery of those molecules to stations. A disruption in supply can affect FCEV drivers negatively.

Although the nameplate dispensing capacity of the hydrogen network exceeds the current reported hydrogen demand, the availability of stations in the network continued to be a problem during the third and fourth quarter of 2021, as seen in Figures 9 and 10, with gradual improvement in the first and second quarter of 2022 as reported in the 2022 Annual Evaluation.[23] Figures 9 and 10, respectively, show the unavailability of hydrogen stations in Northern California and Southern California for the 2021 calendar year.[24] Dates and times that display yellow to red indicate more stations were unavailable at the same time during that period.

Station unavailability in 2021 was mostly caused by supply disruptions. Hurricane Ida in late August 2021 caused power outages and damaged equipment that affected the hydrogen supply chain in the U.S. Gulf Coast, where a large amount of the natural gas used to make

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20 California Code of Regulations Title 17, Division 3, Chapter 1, Subchapter 10, Article 4, Subarticle 7, §95481.

21 California Public Utilities Code §§399.11–399.36 and California Public Resources Code §25741.

22 California Code of Regulations Title 17, Division 3, Chapter 1, Subchapter 10, Article 4, Subarticle 7, §95481.

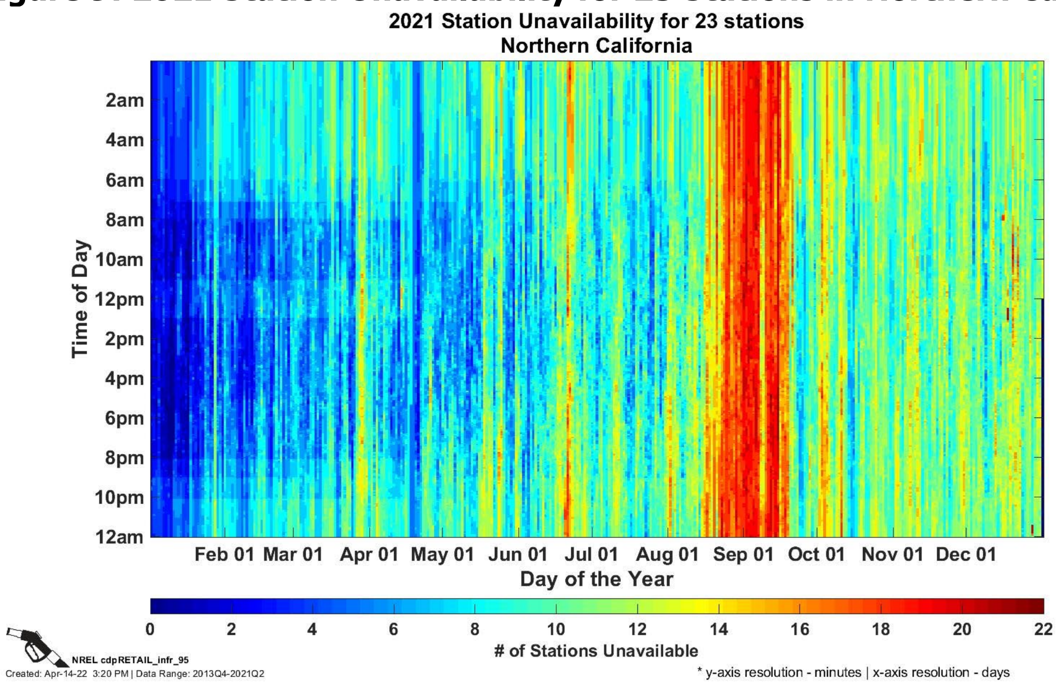
23 California Air Resources Board. September 2022. *2022 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development*. https://ww2.arb.ca.gov/sites/default/files/2022-09/AB-8-Report-2022-Final.pdf.

24 National Renewable Energy Laboratory. "Next Generation Hydrogen Station Composite Data Products: All Stations." https://www.nrel.gov/hydrogen/infrastructure-cdps-all.html.

hydrogen comes from. Issues with downtime at production plants due to unplanned maintenance and recurring problems with delivery truck availability contributed to difficulties of stations, particularly those in Northern California, receiving hydrogen in 2021. However, with the opening of the Livermore hub by FirstElement Fuel and another gaseous hydrogen transfill system becoming operational in Ontario (San Bernardino County), network availability started to improve during the first and second quarters of 2022.

Equipment issues also affect station availability. According to NREL,[25] 61 percent of unscheduled maintenance events from the third quarter of 2014 through the second quarter of 2021 were due to equipment failures. Dispenser failure events were the most common, about half of the total events, followed by compressor failure events. Station operators also reported they have experienced equipment repair delays due to supply chain issues.

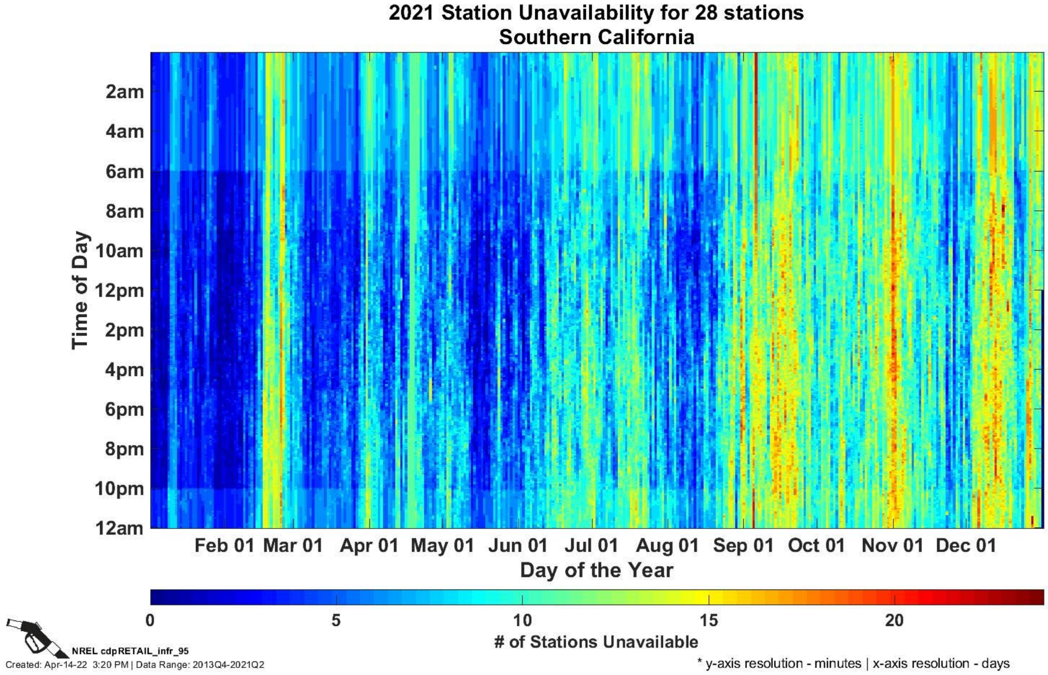
Figure 9: 2021 Station Unavailability for 23 Stations in Northern California



Source: NREL

25 National Renewable Energy Laboratory. "Next Generation Hydrogen Station Composite Data Products: Retail Stations." https://www.nrel.gov/hydrogen/infrastructure-cdps-retail.html.

Figure 10: 2021 Station Unavailability for 28 Stations in Southern California



Source: NREL

Expanding Options for Hydrogen Supply for California

The hydrogen refueling station network can benefit from more hydrogen supply sources. The CEC continues to work toward increasing hydrogen supply source options by including supply requirements in solicitations and by funding renewable hydrogen production plants. For example, GFO-19-602 required stations funded under the solicitation to have a second supply agreement as backup to ensure station operators do not rely on a single supply source. In addition, the Clean Transportation Program has funded four new renewable hydrogen production plants, and an upgrade to an existing plant, with a combined daily nameplate capacity of nearly 24,000 kilograms.[26] Two of these plants are expected to open in 2023. The rest of the plants are still in early stages of development.

In addition to the CEC investment in new hydrogen production, the options for hydrogen supply are increasing from other public and private sector investments. News about expanding options for hydrogen supply for California include announcements from FirstElement Fuel and Air Liquide and new opportunities from investments by the federal government.[27]

In May 2022, Air Liquide officially opened the North Las Vegas plant in Nevada, its largest liquid hydrogen production and logistics infrastructure plant in the world, capable of producing

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26 Two production plants were funded by GFO-17-602, Renewable Hydrogen Transportation Fuel Production Facilities and Systems, released December 2017. Two additional plants and a plant upgrade were funded by GFO-20-609, Renewable Hydrogen Transportation Fuel Production, released April 9, 2021.

27 U.S. Department of Energy. June 2022. "[DOE Launches Bipartisan Infrastructure Law's $8 Billion Program for Clean Hydrogen Hubs Across U.S.](https://www.energy.gov/articles/doe-launches-bipartisan-infrastructure-laws-8-billion-program-clean-hydrogen-hubs-across)" https://www.energy.gov/articles/doe-launches-bipartisan-infrastructure-laws-8-billion-program-clean-hydrogen-hubs-across.

30 metric tons per day to serve various customers, including those in the California FCEV market.[28] This capacity is enough fuel supply for roughly 40,000 FCEVs. A photograph of the plant is shown in Figure 11.

The 2021 Joint Report discussed FirstElement Fuel's new 2,400 kg/day supply agreement with Linde's Ontario hydrogen production plant. This June, FirstElement Fuel began taking hydrogen delivery from Air Liquide's new North Las Vegas hydrogen production plant and receives about 2,500 kg/day.

Figure 11: Air Liquide Hydrogen Plant in North Las Vegas, Nevada

Source: Air Liquide

Other hydrogen production updates since the 2021 Joint Report, including both projects that will serve transportation uses and those that will not, are summarized in the following list.

- HyBuild Los Angeles, the first regional initiative in the HyBuild North America platform, whose goal is to create a green hydrogen ecosystem among stakeholders across North America, seeks to accelerate high-volume supply chains for hydrogen at scale to bring the cost of delivered green hydrogen to less than $2.00 per kilogram. After completing Phase 1 of the initiative, which qualified 1 million to 3 million metric tons per year of potential aggregated demand in the Los Angeles basin, Phase 2 is now underway, which emphasizes equity, pollution reduction, job creation, and economic development.[29]
- Plug Power plans to construct a new green hydrogen production plant in Fresno County with a plan to be open for business in late 2024 to serve the transportation sector. Plug

28 Air Liquide. May 24, 2022. "Air Liquide Inaugurates in the U.S. Its Largest Liquid Hydrogen Production Facility in the World." https://industry.airliquide.us/air-liquide-inaugurates-us-its-largest-liquid-hydrogen-production-facility-world.

29 Green Hydrogen Coalition. "Positioning Los Angeles as North America's First Hydrogen Hub." https://www.ghcoalition.org/ghc-news/hydeal-la-phase2.

Power will use a 300-megawatt solar farm to power 120 megawatts of Plug Power polymer electrolyte membrane electrolyzers to produce 30 metric tons of liquid hydrogen daily.[30]

- The Advanced Clean Energy Storage project in Utah, by Mitsubishi Power and Magnum Development, is designed to ultimately produce up to 100 metric tons per day of hydrogen from renewable energy using electrolysis. The hydrogen will be stored in two underground salt caverns, each capable of storing 150 gigawatt-hours (GWh) of energy to be used in a hydrogen-capable gas turbine combined cycle power plant. The plant is scheduled to be operational by 2025, run on a blend of 30 percent green hydrogen and 70 percent natural gas at first, eventually expanding to 100 percent green hydrogen by 2045. The U.S. DOE closed a $504.4 million loan to the project in June 2022.[31]
- SGH2 Energy and the City of Lancaster will co-own a hydrogen plant based in Lancaster (Los Angeles County) that plans to use recycled wastepaper and recycled water to produce up to 11,000 kilograms of hydrogen daily. The plant is scheduled to be operational in the fourth quarter of 2023 to serve the transportation sector.[32] The CEC has funded this project.
- The U.S. DOE launched clean hydrogen initiatives of the Bipartisan Infrastructure Law this year, making $8 billion available for regional clean hydrogen hubs, $1 billion for a clean hydrogen electrolysis program, and $500 million for clean hydrogen manufacturing and recycling initiatives.[33] These initiatives will likely reduce the costs of hydrogen and related equipment and expand the workforce available for hydrogen-related projects. These positive effects will also likely contribute to expanding the refueling network for light-, medium-, and heavy-duty vehicles in California.
- SoCalGas has proposed developing what would be the nation's largest green hydrogen infrastructure system. The Angeles Link project would deliver green hydrogen into the Los Angeles region via a pipeline system to decarbonize ports and other hard-to-electrify applications. The impact to on-road FCEV applications will be determined in part by demand and market developments in the industry.[34]

The total fueling capacity of the 175-station network is nearly 167,000 kg/day, or enough hydrogen fuel for nearly 238,000 light-duty FCEVs. The combined daily production capacity of existing and new production plants that will supply hydrogen to the transportation sector is about 88,000 kg/day, most of which can be available to use in California. This amount is about

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30 Plug Power, Inc., June 2022. "Plug Power CEC IEPR Workshop." https://www.energy.ca.gov/event/workshop/2022-06/iepr-commissioner-workshop-role-hydrogen-californias-clean-energy-future.

31 Mitsubishi Power Americas. "US DOE Closes $504.4 Million Loan to Advanced Clean Energy Storage Project for Hydrogen Production and Storage." https://power.mhi.com/regions/amer/news/20220609/.

32 CEC project files.

33 U.S. DOE. DOE Establishes Bipartisan Infrastructure Law's $9.5 Billion Clean Hydrogen Initiatives. https://www.energy.gov/articles/doe-establishes-bipartisan-infrastructure-laws-95-billion-clean-hydrogen-initiatives.

34 SoCalGas, May 2022. "Shaping the Future: Informational Webinar on Angeles Link." https://www.socalgas.com/sites/default/files/2022-05/Informational%20Webinar%205.19.pdf.

half the capacity of the future light-duty fueling network (though almost double the anticipated demand of the latest light-duty FCEV projection of 65,600 FCEVs on the road by 2028). Continuing to focus on increasing hydrogen production for the California mobility market, with a focus on clean hydrogen and low carbon intensities, should remain a priority. In addition, more hydrogen production projects, even the ones that will not supply the transportation sector, will help reduce the costs of hydrogen production and delivery in general and advance technologies.

CEC Solicitations for Medium- and Heavy-Duty Hydrogen Infrastructure

The CEC has invested nearly $40 million in medium- and heavy-duty hydrogen infrastructure through several solicitations, which will yield a daily fueling capacity of about 8,700 kilograms based on the nameplate capacity of the projects. This investment in medium- and heavy-duty hydrogen infrastructure, funded by the Clean Transportation Program, is separate from the annual $20 million investment in light-duty hydrogen infrastructure.[35]

Further, the ZEV Package of the 2021 Budget Act prioritizes diesel emission reduction by earmarking funding over three years for 1,125 zero-emission drayage trucks, 1,000 zero-emission school buses, and 1,000 zero-emission transit buses, along with the appropriate charging and refueling infrastructure. The CEC will invest a meaningful portion of the three-year, $1.165 million ZEV Package funding to support electric and hydrogen medium- and heavy-duty vehicle infrastructure.

The 2022 Budget Act expands on the 2021 Budget Act and includes $6.1 billion for transportation and other ZEV-related projects. The CEC will be administering more than $2 billion in funds over the next four fiscal years to continue deployment of ZEV infrastructure to support the goals outlined in Governor Gavin Newsom's Executive Order N-79-20. Of the more than $2 billion in CEC funds, $1.385 billion will fund the infrastructure to power medium- and heavy-duty vehicles and equipment over four years, including infrastructure for drayage trucks, transit buses, school buses, trucks, buses, off-road equipment, and equipment at ports. In addition to the medium- and heavy-duty and off-road infrastructure investments, the multiyear budget includes $60 million that is specific to hydrogen infrastructure.

In early 2022, the CEC launched EnergIIZE, California's first-ever block grant program designed to provide streamlined incentives for fueling infrastructure for zero-emission commercial vehicles. EnergIIZE includes a funding lane specifically for hydrogen refueling infrastructure. Demand for the hydrogen refueling infrastructure lane exceeded the initial funding amount of $17 million, an early indication that demand for fuel cell commercial vehicles is growing in California.

On October 3, 2022, the CEC released GFO-22-502, Innovative Hydrogen Refueling Solutions for Heavy Transport. The solicitation will develop and demonstrate innovative hydrogen

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35 Brecht, Patrick. 2022. *2022–2023 Investment Plan Update for the Clean Transportation Program*. California Energy Commission. Publication Number: CEC-600-2022-053-SD. https://efiling.energy.ca.gov/GetDocument.aspx?tn=242563.

refueling solutions to support the decarbonization of emerging medium- and heavy-duty on-road and off-road vehicle applications, reduce hydrogen delivery and refueling costs, improve reliability, enable higher fill rates, and minimize energy losses. Up to $16.5 million is available for grants under this solicitation from the Gas R&D Program, Zero-Emission Vehicle Infrastructure funding from the Budget Act of 2021, and, potentially, the Clean Transportation Program. The anticipated start date for the resulting agreements is July 31, 2023, and the anticipated end date is March 31, 2026.

Updates to some of the past solicitations mentioned in Table 2 of the 2021 Joint Report include:

- GFO-20-606, Zero-Emission Drayage Truck and Infrastructure Pilot Project: Jointly funded by the CEC and CARB, the Center for Transportation and the Environment was awarded $21,878,132 to develop a 1,600-kilogram-per-day hydrogen refueling station in Alameda County near the Port of Oakland, which is expected to be operational by summer 2023. Initially, this station will serve the 30 CARB-funded Class 8 trucks with a 500-mile range on 60 kilograms of hydrogen.[36]
- GFO-21-501, Hydrogen Fuel Cell Truck and Bus Technology Integration and Demonstration: On March 9, 2022, the CEC approved two projects using research and development funding from the Fiscal Year 2020–2021 Gas R&D Program to demonstrate three advanced hydrogen fuel cell trucks with challenging duty cycles, including industrial gas bulk delivery and extended regional haul across the Central Valley. The demonstration will leverage existing hydrogen refueling stations or temporary refueling solutions. Cummins Electrified Power NA Inc. was awarded $2,000,000, and the Institute of Gas Technology dba Gas Technology Institute was awarded $1,999,667.

FCEV Fueling Infrastructure and Fuel Production: Statewide Assessment

Senate Bill 643 (Archuleta, Chapter 646, Statutes of 2021) requires the CEC, in consultation with CARB and the California Public Utilities Commission, "to prepare a statewide assessment of the fuel cell electric vehicle fueling infrastructure and fuel production needed to support the adoption of zero-emission trucks, buses, and off-road vehicles at levels necessary for the state to meet specified goals and requirements relating to vehicular air pollution ..." by December 31, 2023, and to update the assessment at least every three years.[37] The bill also requires that this assessment complement and not duplicate the AB 8 reports. Therefore, the CEC will be publishing a separate report that focuses on the assessment of the FCEV fueling infrastructure and fuel production needs for trucks, buses, and off-road vehicles in 2023.

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36 Class 8 trucks are trucks with a gross vehicle weight rating of over 33,000 pounds (lbs.). See U.S. Department of Energy, Alternative Fuels Data Center, "Vehicle Weight Classes and Categories." https://afdc.energy.gov/data/10380.

37 California Legislative Information. Senate Bill 643 (Archuleta, Chapter 646, Statutes of 2021). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202120220SB643.

CHAPTER 3: Fuel Cell Electric Vehicle Deployment

This chapter discusses the number of FCEVs in the state and projected FCEV population, along with barriers to widespread FCEV commercialization. The chapter also covers medium- and heavy-duty fuel cell vehicles, as well as other transportation uses.

The cumulative sales and leases of light-duty FCEVs are increasing, but the current network nameplate fueling capacity continues to offer opportunities for faster deployment of FCEVs. However, the actual network fueling capacity depends on the availability of hydrogen supply and the availability of the stations themselves. Figures 9 and 10 in Chapter 2 of this report show the station unavailability in California in 2021.

Both the CEC and CARB publish FCEV deployment numbers. The CEC Energy Assessments Division collects and analyzes California Department of Motor Vehicles (DMV) data about the trends in ZEV sales and population. CARB also collects and reports the estimated number of FCEVs on the road in April and October each year based on the analysis of DMV data, including removing vehicles that appear to be no longer registered in the state.

The CEC publishes "Zero Emission Vehicle and Infrastructure Statistics,"[38] which offers a collection of dashboards for ZEV sales, ZEV population, school buses, and corresponding infrastructure information. The New ZEV Sales in California dashboard reports that the on-road population of FCEVs was 10,127 at the end of 2021, and the dashboard also reports the new FCEV sales for 2022, through the end of the third quarter, as 2,042 FCEVs. With this information, staff estimates the total on-road FCEV population to be 12,169, the summation of 10,127 and 2,042.[39] The dashboard shows cumulative ZEV sales, including FCEV, BEV, and plug-in hybrid electric vehicles, of 1,304,581 in California as of the third quarter of 2022.

The CARB's analysis of DMV data found the population of FCEVs was 11,134, as of April 2022. Per the provision set forth by AB 8, CARB is "to aggregate and make available to the public, no later than June 30, 2014, and every year thereafter, the number of hydrogen-fueled vehicles that motor vehicle manufacturers project to be sold or leased over the next 3 years, as reported to the state board, and the number of hydrogen-fueled vehicles registered with the Department of Motor Vehicles through April 30."[40] AB 8 also requires the CEC and CARB to consider "the available plans of automobile manufacturers to deploy hydrogen-fueled vehicles

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38 California Energy Commission. "Zero Emission Vehicle and Infrastructure Statistics." https://www.energy.ca.gov/zevstats.

39 According to the CEC ZEV Dashboard, cumulative sales or leases of FCEVs in California were 13,998 in the third quarter of 2022; however, the cumulative sales number of FCEVs does not account for those FCEVs no longer in use due to replacement or attrition.

40 California Legislative Information. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB8.

in California and their progress toward achieving those plans, the rate of deployment of hydrogen-fueled vehicles, …" and other factors.

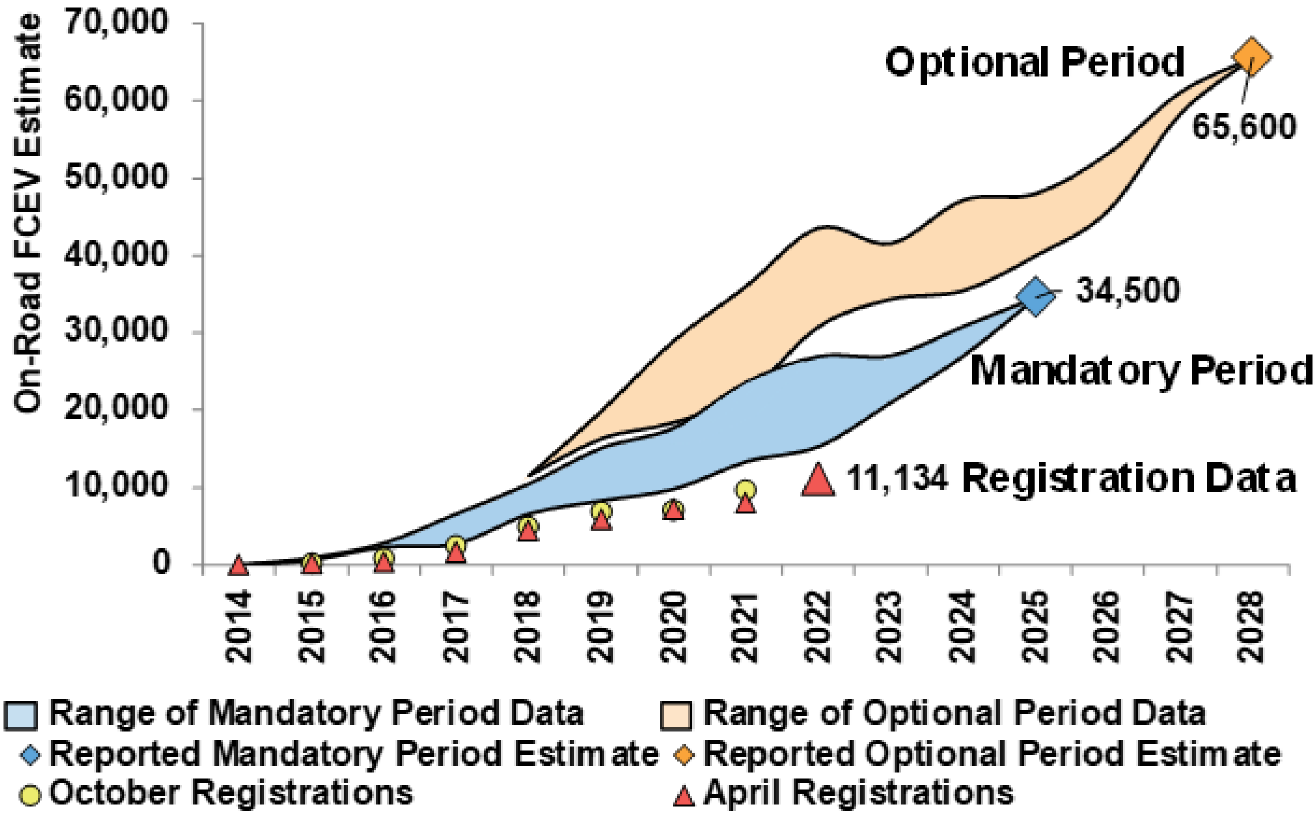
Figure 12, reprinted from CARB's 2022 Annual Evaluation, shows data as provided by auto manufacturers for estimates of vehicles on the road and projected for future deployment from all years of reporting in CARB's Annual Evaluations. CEC staff notes that the material in Figure 12 are projections, per AB 8. Estimated numbers of vehicles on the road per CARB's annual analysis of April 2022 DMV registration data are shown by the red triangles, growing to an estimate of 11,134.

In Figure 12, yellow circles show similar data based on October DMV data. Two shaded areas are also shown in the figure, representing projections made by auto manufacturers for future FCEV deployment in all annual evaluations to date. For each annual evaluation, auto manufacturers submit projections to CARB of future FCEV deployment, split into two periods. All auto manufacturers must provide estimates for the mandatory period, which always covers the current model year and the next three model years. Auto manufacturers may also provide responses for the optional reporting period, which extends three further model years. For example, in the 2022 survey, the mandatory period covers the Model Years 2022 through 2025, and the optional period covers Model Years 2026 through 2028. In Figure 12, the lower, blue-shaded area displays results for mandatory periods in all past surveys, while the upper, orange-shaded area displays results for optional periods in all past surveys. The information provided on the survey, by auto manufacturers, represents projected FCEV sales or leases in terms of model years. CARB's analysis translates model year into calendar year by assuming that one-third of all vehicles of a given model year are sold or leased in the prior calendar year. For example, if an auto manufacturer responds with a projection of 900 FCEVs to be sold in Model Year 2022, CARB's analysis assumes 300 FCEVs will be sold in Calendar Year 2021 and the remaining 600 FCEVs in Calendar Year 2022. CARB's analysis also assumes a standard rate at which FCEVs fall out of the fleet, such as vehicles being moved to another state, accidents, and other causes. This rate is based on similar assumptions in CARB's vehicle fleet modeling tool EMFAC.

Auto manufacturers' deployment plans in the 2022 annual survey would result in 34,500 FCEVs on the road in California in 2025 and 65,600 on the road in 2028. The projected rates of growth are similar to what was observed in the 2021 survey. The 2028 projected FCEV population of 65,600 is less than a quarter of the 274,000 FCEVs that the anticipated fueling network of 200 stations could support based on the nameplate capacity of the stations, assuming future remaining stations will each have an average of 1,000 kg/day capacity. Even with the assumption that stations would dispense no more than 80 percent of nameplate capacity in real-world operating conditions, auto manufacturers could still triple FCEV deployment plans for 2028.

The CEC designed the multiyear funding strategy of GFO-19-602 to enable station equipment cost savings and continuous hydrogen refueling station development. With more regularity and certainty in station deployment, the intention is to expedite market growth and enable auto manufacturer FCEV deployment projections to accelerate. Market confidence should also grow with maturation of hydrogen equipment and distribution supply chains.

Figure 12: FCEV Projections Based on CARB Analysis of Responses to the Annual Auto Manufacturer Survey



Source: CARB

Addressing Barriers to Widespread FCEV Commercialization and Deployment

The 2021 Joint Report identified various barriers to widespread FCEV commercialization and deployment. The CEC continues to explore options to enhance the hydrogen station network reliability, resiliency, and availability by working with station developers and operators who have agreements with the CEC and by setting requirements in future solicitations. In addition, CEC, CARB, and GO-Biz staff are in the planning phase for conducting an FCEV driver survey to learn about FCEV driver experiences and what they would like to see in the hydrogen station network. CEC, CARB, and GO-Biz staff plan to present the findings from the survey at a future workshop.

Medium- and Heavy-Duty Fuel Cell Vehicles and Beyond

Hydrogen use in transportation in California is expanding to medium- and heavy-duty FCEVs: buses, trucks, portside equipment, a locomotive, and a commuter rail system. The California Climate Investments Program funds medium- and heavy-duty fuel cell electric vehicles, in addition to the CEC investments in medium- and heavy-duty fuel cell vehicle infrastructure. The California Climate Investments Program also funded a demonstration project for a 75-

passenger ferry that is powered by hydrogen fuel cells.[41] The private sector is also making investments. Volvo Trucks has started to test fuel cell electric trucks, and it plans for commercialization of the trucks for the latter part of this decade. In California, BNSF Railway Company and Chevron U.S.A. Inc., announced in December 2021 a collaboration to advance the demonstration of a locomotive powered by hydrogen fuel cells. The demonstration seeks to confirm the feasibility and performance of hydrogen fuel for use as a viable alternative to traditional fuels for line-haul rail.[42]

CARB's Innovative Clean Transit Rule (ICT) is a regulation that requires public transit agencies in California to switch to zero-emission (electric or fuel cell) buses and submit rollout plans to CARB.[43] CARB has invested in several projects for medium- and heavy-duty fuel cell vehicles through the California Climate Investments program[44] and Volkswagen (VW) Mitigation Trust Fund,[45] as reported in the 2021 Joint Report. According to the CEC ZEV Dashboard, there are 1,308 battery-electric buses (BEBs) and 61 fuel cell electric buses (FCEBs) registered in California. Table 2 shows transit agencies with FCEBs in service. In addition, according to CARB staff, there are more FCEBs on order that will be in operation in the future, including 33 FCEBs by the Foothill Transit Agency, which provides bus service to San Gabriel and Pomona Valleys in Southern California.

A comprehensive review by NREL and University of California, Berkeley, of the rollout plans submitted to CARB indicated that transit agencies are planning to purchase about 8,000 zero-emission buses (ZEBs) over the following 20 years. Of those, around 1,200 will be FCEBs, 5,250 will be BEBs, and the remaining 1,550 ZEBs, whether they will be FCEBs or BEBs, has not been determined.[46] The review noted that the balance of purchases between the two technologies may shift depending on a variety of factors, such as fuel or charging availability and costs. The Alameda-Contra Costa Transit District (AC Transit), the third-largest public bus system in California, serving 13 cities and adjacent unincorporated areas in Alameda and Contra Costa counties, submitted a revised rollout plan to CARB in June 2022, shifting its procurement plan from 30 percent to 70 percent FCEBs. The revised plan notes the

41 Reuters. April 21, 2022. "Hydrogen-Powered Ferry Prepares to Launch in San Francisco Bay." https://www.reuters.com/world/us/hydrogen-powered-ferry-prepares-launch-san-francisco-bay-2022-04-21/.

42 Chevron, December 2021. "Caterpillar, BNSF and Chevron Agree to Pursue Hydrogen Locomotive Demonstration." https://www.chevron.com/newsroom/2021/q4/caterpillar-bnsf-and-chevron-agree-to-pursue-hydrogen-locomotive-demonstration.

43 California Air Resources Board. "Innovative Clean Transit (ICT) Regulation Fact Sheet." https://ww2.arb.ca.gov/resources/fact-sheets/innovative-clean-transit-ict-regulation-fact-sheet.

44 California Climate Investments. http://www.caclimateinvestments.ca.gov/.

45 California Air Resources Board. Volkswagen Environmental Mitigation Trust for California. https://ww2.arb.ca.gov/our-work/programs/volkswagen-environmental-mitigation-trust-california.

46 Jeffers, Matthew, Kenneth Kelly, Timothy Lipman, Andre Fernandes Tomon Avelino, Caley Johnson, Mengming Li, Matthew Post, and Yimin Zhang. *Comprehensive Review of California's Innovative Clean Transit Regulation: Phase 1 Summary Report.* https://ww2.arb.ca.gov/sites/default/files/2022-08/ICT-ComprehensiveReview-Phase1_0.pdf.

construction of new hydrogen refueling infrastructure at the AC Transit bus facility in Hayward with commissioning planned in late 2026.[47]

Table 2: FCEBs Registered in California

Transit Agencies with FCEBs In-Service	Quantity
Alameda-Contra Costa Transit District	29
Golden Empire Transit District	5
Orange County Transportation Authority	10
Sunline Transit Agency	17
Total	**61**

Source: CEC ZEV Dashboard

The SCAQMD also continues to cofund projects to support hydrogen refueling infrastructure. Table 3 shows an updated list of projects for medium- and heavy-duty FCEVs that SCAQMD supports.

Table 3: SCAQMD Projects for Medium- and Heavy-Duty FCEVs

Project	Description
Class 8 Fuel Cell Truck Demonstration (SCAQMD and U.S. EPA cofunding)	To demonstrate two Hyundai fuel cell electric trucks (FCETs) on existing goods movement routes utilizing three existing CEC-funded hydrogen refueling stations
High-Flow Bus-Fueling Protocol Development (SCAQMD funded)	To model, test, and validate the application of a protocol for high-flow bus fueling based on the formula originally developed and applied to passenger car fueling
Contract With NREL to Support California Hydrogen Heavy-Duty Infrastructure Research (SCAQMD funded)	To develop a heavy-duty hydrogen reference station, fueling performance test device concepts, and a heavy-duty hydrogen station capacity model
Zero-Emission Multiple Unit Train (SCAQMD- Mobile Source Air Pollution Reduction Review Committee (MSRC) funded)	To demonstrate a battery and hydrogen-powered passenger train between San Bernardino and Redlands operated by the San Bernardino County Transportation Authority (SBCTA)

47 AC Transit. 2022. *Zero Emission Bus Transition Plan*. https://www.actransit.org/sites/default/files/2022-06/0162-22%20ZEB%20Transition%20Plan_052022_FNL.pdf.

Project	Description
Contract With UC Davis for the California Hydrogen Systems Analysis (SCAQMD and various cofunders)	To develop and/or use various models to look at spatial representations of fuel cell vehicles around California, hydrogen supply/demand, and geographic need for infrastructure The CEC is also a cofunder of this contract
Contract With A-1 Alternative Fuel Systems for Hydrogen Fuel Cell Buses (SCAQMD funded)	To develop, demonstrate, and commercialize hydrogen fuel cell medium-duty buses
Long-Range Class 8 Fuel Cell Truck Demonstration (U.S. EPA funded)	To demonstrate five long-range Class 8 Hyundai hydrogen fuel cell trucks
Fuel Cell Transit Bus Deployment (U.S. EPA and SCAQMD funded)	To deploy five fuel cell transit buses at Sunline Transit Agency

Source: Project information from SCAQMD

CHAPTER 4: Time Required to Permit and Construct Hydrogen Refueling Stations

Chapter 4 covers the station development time, shows how the development time has changed over the years, and discusses efforts to help reduce station development time.

The overall station development times were decreasing until the COVID-19 pandemic slowed many station development activities. Time required to permit and construct hydrogen refueling stations observed during the pandemic may not be an accurate representation of the progress the industry has made in reducing station development time. In addition to the pandemic-related delays reported in the 2021 Joint Report, station developers have been experiencing supply chain issues, including labor and material shortages. This report breaks down station development time into four phases to analyze the trend. Table 4 lists the phases of station development.

Table 4: Station Development Phases

Phases	Description	Responsible Entity(ies)
Phase One: From start of CEC grant-funded project to initial permit application filing	Begins when the grant-funded project agreement is executed and includes site selection and site control, station planning, participation in prepermitting meetings for confirmation of station design consistency with local zoning and building codes and filing the initial permit application with the authority having jurisdiction (AHJ). Equipment ordering could occur during this phase.	Grant recipient and AHJ
Phase Two: From initial permit application filing to receipt of approval to build	Consists of AHJ review of the application and potential site reengineering/redesign based on AHJ feedback. Minor construction work sometimes begins.	Grant recipient and AHJ
Phase Three: From approval to build to station becoming operational	Includes station construction and meeting operational requirements: fuel supply, hydrogen quality testing, dispensing per standard, successful refueling of one FCEV, and receipt of an occupancy permit from the AHJ.	Grant recipient and AHJ

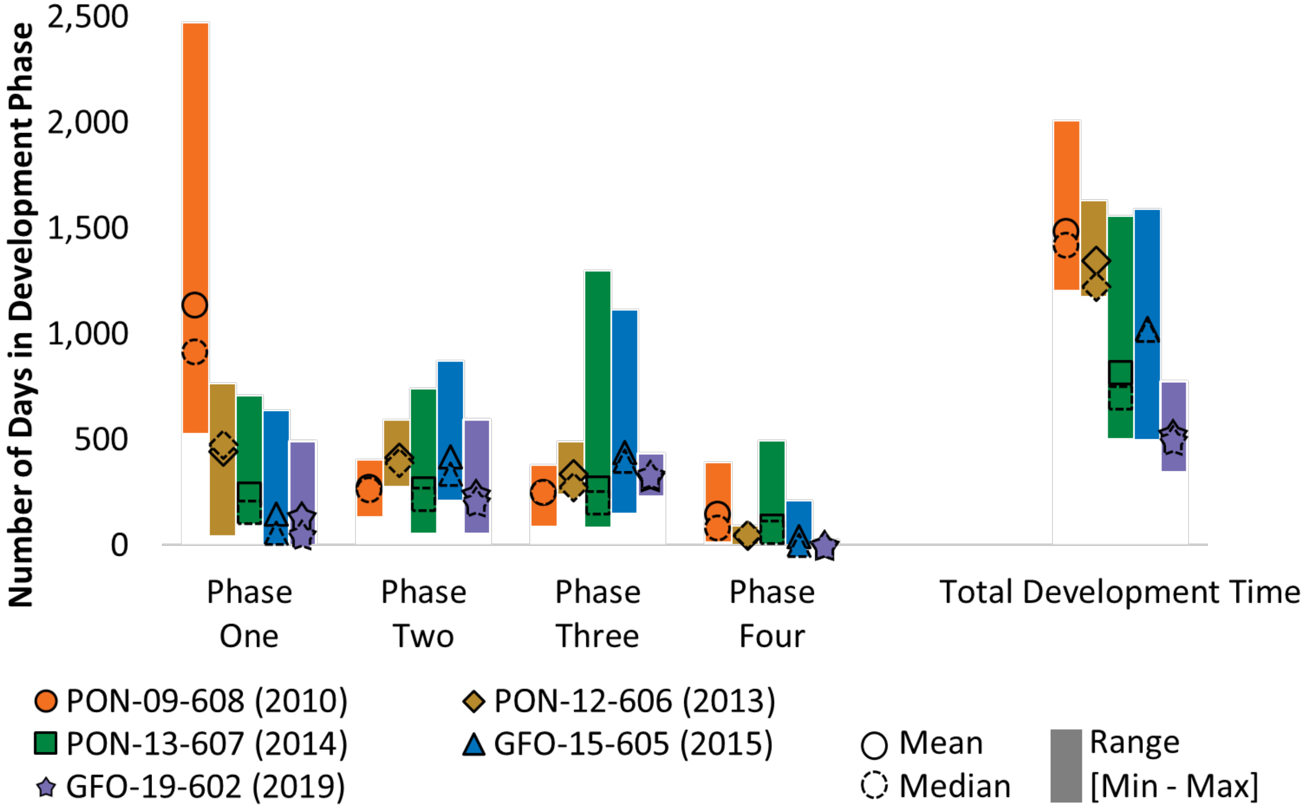
Phases	Description	Responsible Entity(ies)
Phase Four: From station becoming operational to becoming open retail	The station undergoes accuracy testing with the California Department of Food and Agriculture/Division of Measurement Standards (DMS) and protocol testing with auto manufacturers and the Hydrogen Station Equipment Performance (HyStEP) device. Once the station has been confirmed to meet the refueling protocol, the station is categorized as open retail.	Grant recipient, DMS, CARB (HyStEP), and auto manufacturers

Source: CEC

Figure 13 presents station development time, showing mean, median, minimum, and maximum number of days for each phase with one bar representing all the stations funded in one solicitation. A *mean number of days* simply represents the average number of days for all stations that completed each phase. Mean numbers can be affected by unusual circumstances some stations experience that lead to atypical station development time. A median number of days represents the middle value of the reported number of days for all stations that completed each phase. Median numbers represent more typical station development time. Minimum and maximum numbers of days represent the minimum and maximum time spent in each phase for all stations that completed each phase. The figure includes data from stations that are not yet open for retail fuel sales, but only includes data for those stations for the completed phases. The bars on the far right in the figure show mean, median, minimum, and maximum numbers of days for the *total* station development time for each solicitation and include *only stations that have completed all phases*.

Figure 13 shows, per solicitation, the actual time station projects spent in each phase; therefore, the time spent in development phases includes data of stations that were canceled without completing or stations that have closed. For example, four station projects were canceled during 2022, but these stations had completed Phase One, and the associated data are included in the corresponding solicitation bars for Phase One. The Phase One development time is *not* represented in the Total Development Time bars because the stations did not complete all phases.

Figure 13: Mean, Median, Minimum, and Maximum Days of Each Station Development Phase by Solicitation



Overall, the time spent in Phase One continues to decrease significantly after 2010 for newer solicitations. The mean, median, and maximum of station development time for newer stations continue to increase as more stations completed. The median station development time for GFO-19-602 is significantly lower than the other solicitations, but only eight stations have completed all phases, and the rest of the stations are in development and still affected by the COVID pandemic effects.

Sources: CEC and CARB

The past joint reports observed an overall decrease in station development time with each subsequent solicitation. However, the station development time (mean, median, and maximum) in Phase Three for GFO-15-605 has increased as more stations funded under this solicitation completed since data were last reported in the 2021 Joint Report. As the remaining stations under GFO-15-605 are completed, the mean, median, and maximum numbers for this solicitation will continue to increase.

Stations funded under GFO-15-605 that are still under development have experienced unforeseen delays, such as:

- Changes in site lease agreements for the stations.
- Temporary hydrogen supply disruptions slowing station testing.
- Energizing stations taking longer than expected.
- Station developers experiencing technology problems with equipment.
- Slower permitting in some cases due to disruptions caused by the COVID-19 pandemic.

- Scheduling lags for final inspections with utilities due to backlogged work caused by the pandemic.
- Delays in equipment delivery from overseas due to the pandemic.

The station development time for GFO-19-602 continues to be updated as more stations complete the development phases. Only eight GFO-19-602 stations have completed all phases. Of these eight stations, seven stations are privately funded stations that are counted as match in an agreement resulting from GFO-19-602. These stations opened quickly because the station developer had already started on permitting those stations before they applied for GFO-19-602. The solicitation included benchmarks for developers to receive approval to build from the respective authority having jurisdiction within 18 months of the CEC approving the station and becoming open retail within 30 months of the CEC approving the station. These benchmarks appear to be helping keep station development on track for most stations.

In 2021, CEC staff expected the overall station development time (mean, median, and maximum) for GFO-19-602 to be less than those in previous solicitations as the COVID-19 pandemic effects wind down. However, station developers have reported that the COVID-19 pandemic continues to affect station development. One developer reported persistently slower AHJ application processing, and another developer is facing longer lead times for station equipment without an option to expedite orders. Inflation increased the costs of developing stations, which required station developers to spend additional time to come up with the funds to cover increased expenses. One developer reported a 25 percent to 45 percent cost increase in equipment due to global inflation and increase in global demand for equipment. Labor and material shortages and supply chain interruptions also affect the price and ability to secure construction contracts. Until the global inflation, labor and material shortages, and supply chain interruptions are resolved, staff expects overall station development time for remaining stations to continue to increase.

The station development time (mean, median, and maximum) in Phases One and Three has increased for GFO-19-602. The station development time (mean and maximum) in Phase Four has also increased slightly for GFO-19-602, but this is expected because more stations completed Phase Four this year. The station development time in Phase Two for GFO-19-602 is less than other solicitations because the station developer had already started on permitting those stations before they applied for GFO-19-602.

Efforts to Help Reduce Station Development Time

CEC staff plans to emphasize the importance of readiness when evaluating projects and applicants in future hydrogen infrastructure solicitations, along with other criteria. Staff plans to consider, among other things, applicants' awareness of hurdles currently experienced by station developers and preparedness to overcome those hurdles.

The time required to complete Phase Four has generally decreased with each new solicitation. In the time between PON-13-607 and GFO-15-605, CARB, the CEC, GO-Biz, and DMS collaborated with public and private stakeholders to develop the HyStEP device and program. The HyStEP device tests the ability of hydrogen refueling stations to adhere to the fueling protocols of the industry-adopted SAE J2601 standard. This standard protocol helps ensure fast, safe, and reliable fueling experiences for customers. The HyStEP device accomplishes the task of verifying conformance to the protocol in one to two weeks. Prior efforts that relied on testing via multiple auto manufacturers using test vehicles could require months of scheduling, testing, adjusting, and retesting. The HyStEP program is operated by CARB, with collaborative review of HyStEP testing results among state agencies, the station developer, and auto manufacturers. This review provides one of several indications that a station is ready to fuel vehicles in a retail setting.

Evolution of station technology and design indicates that adjustments to the tools and the program are necessary to meet the needs of future market expansion. CARB is requesting proposals for the design, construction, testing, validation, and delivery of a new HyStEP 2.0 device. The HyStEP 2.0 device will include new hardware and capabilities that enable faster testing, testing of fueling protocols for larger vehicle tank sizes, and testing of back-to-back fill performance. Depending on the availability of applicable standards and proposed designs, the device may also be able to test for adherence to medium- and heavy-duty hydrogen fueling protocols. HyStEP 2.0 is expected to be testing hydrogen stations in California by early 2025. Once developed, the original HyStEP and HyStEP 2.0 devices would be used to perform testing at stations across the state.

In addition, as the in-state hydrogen refueling network grows, station development is expected to accelerate and include increasing amounts of private funding. In fact, there are several stations in development today that are fully privately funded. Station testing with HyStEP is required only by the contractual agreements of stations that receive public funds, and repeat testing to ensure ongoing compliance is not addressed by any current program. DMS is developing a proposed rulemaking that would require all stations in the state to ensure ongoing compliance with SAE J2601 via the test method CSA HGV 4.3 that is used by the HyStEP device. This requirement would apply to all stations regardless of funding source and require proof of compliance periodically. These requirements may also promote the development of a third-party testing industry to help address the expected increase in workload for testing hydrogen fueling stations. CARB staff is collaborating with DMS to develop the proposed rule. A prerulemaking workshop was held August 11, 2022, and a final rule may become effective in 2023.

CHAPTER 5: Amount and Timing of the Growth of the Hydrogen Refueling Network

This chapter compares the anticipated schedule of hydrogen refueling station openings over the next six years to the estimated schedule of FCEV deployment in California. The objective is for the fueling capacity of the station network to stay well ahead of hydrogen fuel demand so that consumers can have confidence in fuel availability if they choose to drive a FCEV. This chapter concludes with contextual information about station and FCEV deployment in other parts of the world.

This report uses the nameplate capacity of stations to analyze the amount and timing of the growth of the hydrogen refueling network in California, discuss the statewide network of stations, and then evaluate the anticipated growth in greater detail at a regional level. This analysis assumes that stations within the network are operating regularly without significant downtime. The validity of this analysis depends on the degree to which stations are actually functioning this way in the real world — they have hydrogen supply available to dispense and are up and running. If stations are down due to broken equipment or because they have run out of hydrogen fuel, the station network cannot support the number of FCEVs that they should on paper. Chapter 2 discusses challenges with hydrogen supply and other factors that have at times significantly affected station network performance.

As of November 11, 2022, California has 62 open retail hydrogen refueling stations that serve California FCEV drivers. These stations can dispense up to 35,000 kilograms of hydrogen per day. However, the actual network fueling capacity depends on the availability of hydrogen supply and the availability of stations themselves. Figures 9 and 10 in Chapter 2 of this report show the station unavailability in California in 2021.

As of November 11, 2022, California has built almost four times more dispensing capacity than the demand needed to fuel its population of FCEVs. The station opening timelines provided to the CEC by hydrogen station developers suggests that by 2027, the network of 175 projected stations will have the capacity of serving nearly 238,000 FCEVs. This number is more than three times the amount of fuel needed to supply the projected 65,600 FCEVs by 2028 reported in CARB's 2022 Annual Evaluation, based on the latest auto manufacturer survey responses.

Even though station capacity should still exceed fuel demand, there have been setbacks related to several station projects in 2022. A recipient of an award funded in 2011 under PON-09-608 canceled two stations after experiencing site relocations due to sites becoming unviable for various reasons, including site lease issues, equipment siting restrictions, and stalled permitting processes. Another recipient of an award funded in 2017 under GFO-15-605 decided to cancel two stations because of issues in obtaining site control and permitting.

Regional Analysis of Network Growth and FCEV Deployment

This section evaluates four major regions of the state: the Greater Los Angeles Area, the San Francisco Bay Area, the Sacramento Area, and the San Diego Area. The regions are defined in the glossary. Also evaluated is the rest of the state, composed of the North Region, Central Coast, Central Valley, Eastern Sierra, and Imperial County.

Table 5 presents the estimate of FCEV registrations per region as of April 2022 compared to the regional capacity of open retail stations. The largest regions of the Greater Los Angeles Area and the San Francisco Bay Area have more than sufficient fueling capacity for the number of FCEVs registered in the area, although station downtime can mean there are still times when fuel is unavailable. The region with most urgent need of additional fueling capacity is the San Diego Area, which is essentially at capacity and unable to serve additional FCEVs. Several stations are in development in San Diego, with one expected to open in early 2023.

Table 5: Regional FCEVs and Open Retail Station Capacity

Region	# of FCEVs[48]	Estimated # of FCEVs Open Retail Stations Can Support[49]	Additional # of FCEVs that Open Retail Stations Could Support
Greater Los Angeles Area	6,858	28,200	21,300
San Francisco Bay Area	2,938	18,900	16,000
Sacramento Area	762	2,000	1,200
San Diego Area	382	400	-
Rest of State	194	1,100	900
Total	11,134	50,600	39,400

Source: CEC

Table 6 presents projections of vehicle and station rollout in 2028. The stations with known locations that are planned to be opened by 2028 are expected to have sufficient nameplate capacity to serve the number of FCEVs projected to be sold by that year as reported in CARB's 2022 Annual Evaluation based on the latest auto manufacturer survey responses. The total capacity of all 175 anticipated stations will have the nameplate capacity to serve more than three times the projected number of FCEVs. Also, the new CEC solicitation, GFO-22-607, funded with the one-time funding from the 2021 Budget Act, provides an opportunity for the CEC to close the gap to 200 stations. As public and private entities work to make this planned

48 Numbers of FCEVs determined by DMV registration data, April 2022.

49 The estimated numbers of FCEVs supported are displayed with rounding to the nearest hundred in this table to better show regional differences. Elsewhere in this report, the statewide estimates are rounded to the nearest thousand.

station network a reality, the state intends to provide the fueling infrastructure that has the capacity to support an increased FCEV population to achieve ZEV deployment goals.

Noticeable, however, is the limited opportunity for FCEV deployment in the rest of the state outside the four main urban regions, as shown in Table 6. Because opening new markets, including the larger urban areas around Eureka, Redding, Stockton, Fresno, Bakersfield, Monterey, San Luis Obispo, and Santa Barbara will be important for FCEV adoption to take hold statewide, station developers should consider locating future planned stations in these areas. To aid in this expansion of stations in the rest of the state, GFO-22-609 encourages station development into these secondary markets.

Table 6: Regional Projection of FCEVs and Station Network Capacity in 2028

Region	Projected # of FCEVs in 2028[50]	Estimated # of FCEVs Stations Could Support in 2028	Additional # of FCEVs That Stations Could Support in 2028
Greater Los Angeles Area	39,600	73,100	33,500
San Francisco Bay Area	19,200	39,100	19,900
Sacramento Area	2,400	4,200	1,800
San Diego Area	3,700	7,800	4,100
Rest of State	700	1,100	400
Total	65,600	125,300	59,700

Source: CEC

The regional analysis in this chapter evaluates all open retail stations, the planned stations under CEC solicitations with confirmed addresses, and planned stations that are privately funded.

To confirm station addresses under GFO-19-602, in which station developers build stations in batches, developers must meet various milestones to prove location viability. There are 42 stations with addresses out of the 111 new stations that the CEC expects to result from GFO-19-602, once fully funded. As station developers confirm the addresses for the remaining planned stations, those stations will be added to this analysis in the 2023 Joint Report. Network nameplate capacity will nearly double from the 2028 capacity listed in Table 6 once all planned station locations are added.

To calculate the projections presented in Table 6, staff used the daily station capacity as determined by the Hydrogen Station Capacity Evaluation (HySCapE) tool (or the stated nameplate capacity, if HySCapE results are not available). Then, staff used the assumption of

50 CARB assigned the proportion of projected vehicles based on the auto manufacturers survey responses to each county based on the proportion of network capacity among stations located within the county. This method assumed the regional distribution of FCEV deployment will closely follow the regional distribution of the fueling network.

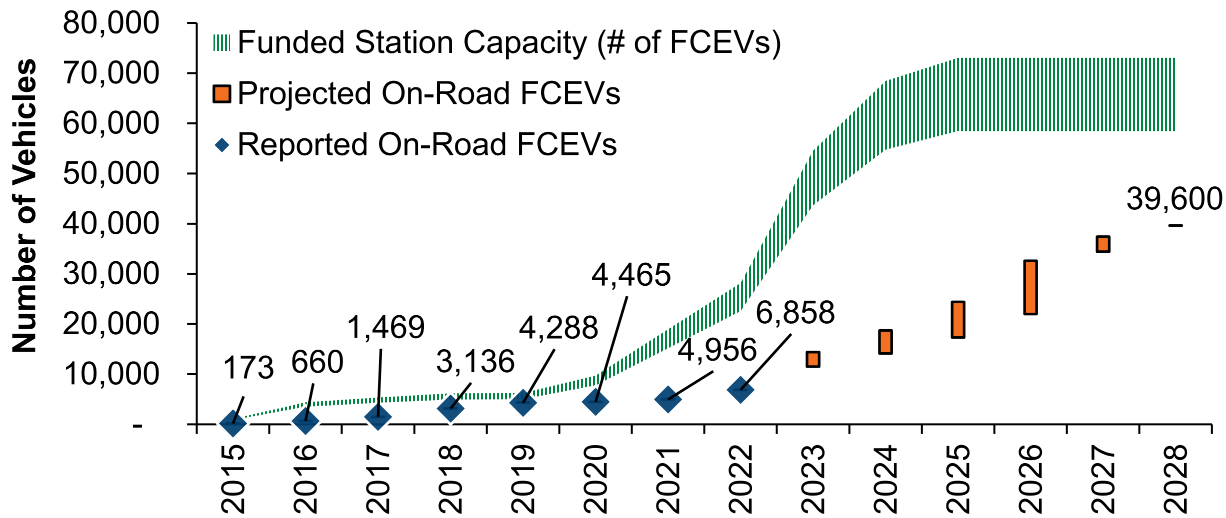
0.7 kilogram per day of hydrogen consumed per FCEV to convert the station nameplate capacity into the estimated number of FCEVs supported.

Figures 14 through 17 compare the estimated FCEV rollout to the estimated regional station deployment based solely on the network of stations with known locations. The orange bars in Figures 14 through 17 show the range of FCEVs projected from auto manufacturer surveys. The figures assume that stations will open according to station developers' timelines.

The green lines in the figures indicate the estimated number of FCEVs that could be supported by a region's stations. The width of the green line represents the difference between using 100 percent of the station nameplate capacity to determine the number of FCEVs supported (the upper bound) and using 80 percent (the lower bound, representing a more sustainable level of fueling).

Figure 14 shows that the FCEV population in the Greater Los Angeles Area has largely followed capacity growth, increasing over time at a similar rate. Currently, the region has the potential to sustain accelerated FCEV deployment, with this potential growing even more in 2023 and 2024, when more stations are scheduled to open. This region, particularly in Los Angeles and Orange Counties, is poised to be able to support at least 55,000 by the end of 2024.

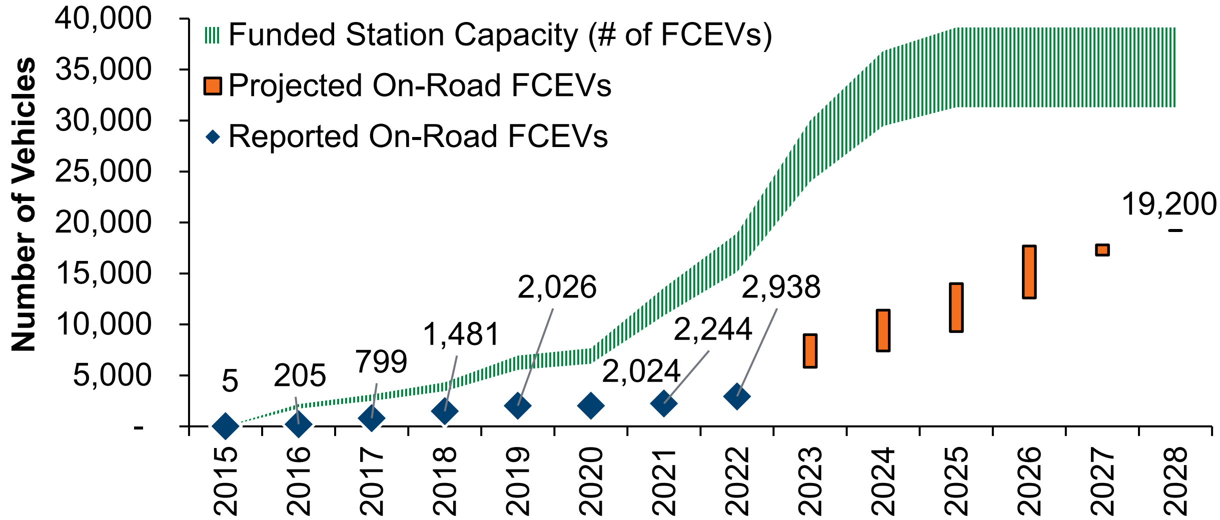
Figure 14: Greater Los Angeles Area Station Capacity and Number of Vehicles



Source: CEC

Figure 15 shows that the network capacity in the San Francisco Bay Area is maintaining a healthy amount of excess capacity to serve FCEVs. With a similar jump in network capacity expected in 2023 and 2024 as in the Greater Los Angeles Area, the Bay Area should have capacity to serve at least 30,000 FCEVs by the end of 2024. This number of FCEVs is a roughly tenfold increase from today's number of FCEVs on the road in the Bay Area.

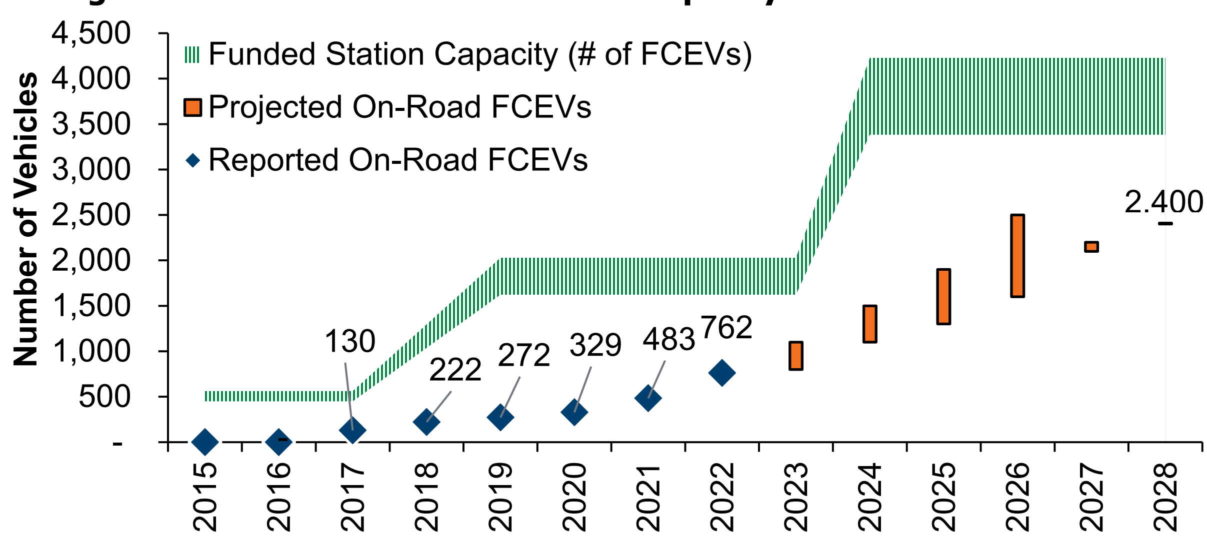
Figure 15: San Francisco Bay Area Station Capacity and Number of Vehicles



Source: CEC

Figure 16 shows that the current network capacity of the Sacramento region is enough to support existing FCEVs, but there is less excess capacity here than the two regions already presented. Two new station locations in the region are not expected until 2024, so additional growth in Sacramento may be limited until then, especially if there is significant station downtime.

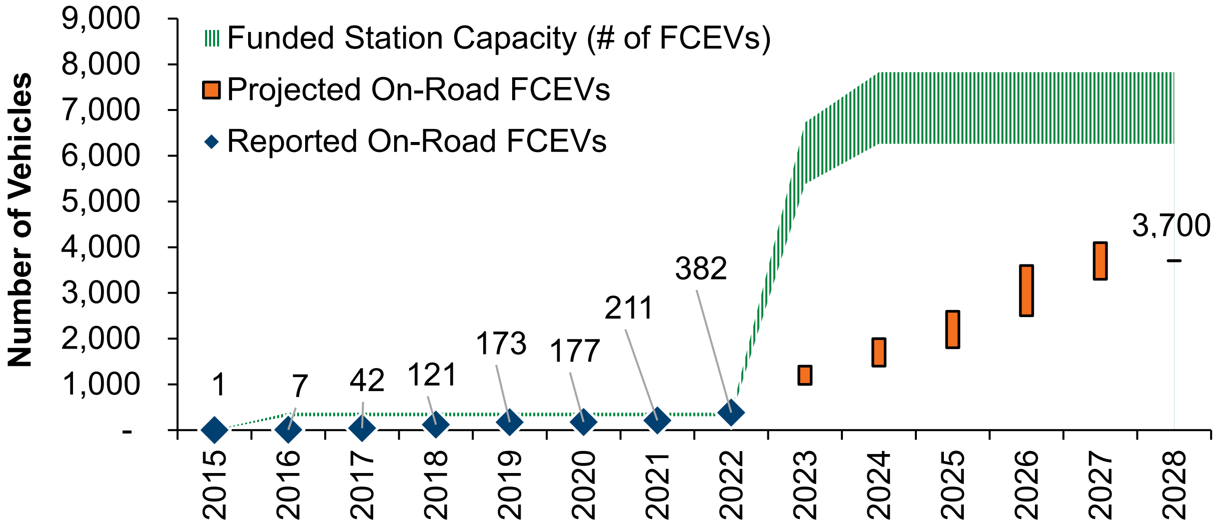
Figure 16: Sacramento Area Station Capacity and Number of Vehicles



Source: CEC

Figure 17 shows San Diego's network has been and continues to operate near capacity, which is 266 kilograms per day at one station near Del Mar. A handful of new stations are planned for the region and should open in 2023 and 2024, but additional fueling locations in this region are needed to provide wider coverage.

Figure 17: San Diego Area Station Capacity and Number of Vehicles



Source: CEC

FCEVs and Stations in Other Countries

The CEC and CARB staffs recognize that for FCEVs and hydrogen infrastructure to scale globally, there must be initial investments by other governments. CEC staff asked representatives of national governments and organizations[51] about current and future investments from their governments in hydrogen refueling infrastructure, station development numbers, FCEV population, and goals. This section presents the findings for the countries making the largest investments: China, Germany, Japan, and the Republic of Korea (South Korea).

Based on the responses CEC staff received about government funding for hydrogen refueling infrastructure, the total cumulative investment made by Germany, Japan, and South Korea plus California through 2021 is nearly $1.3 billion. This total includes about $119 million for Germany, about $740 million for Japan, and about $257 million for South Korea.[52] On a per capita basis, California ranks third after Japan and South Korea in terms of government funding for public hydrogen stations. In addition, these governments have committed more than $400 million in additional investments: $113 million for California, $60 million for Germany, $65 million for Japan, and $163 million for South Korea.[53] Figures 18 and 19 show cumulative investments by California and these countries through 2021 and cumulative investment per capita, respectively. South Korea made a significant funding commitment in 2022 with a plan to develop 138 more stations to achieve the goal of having 310 stations in 2022. The responses did not include any information on new funding in China, but China has more stations and vehicles compared to the numbers CEC staff received last year. Zhangjiakou

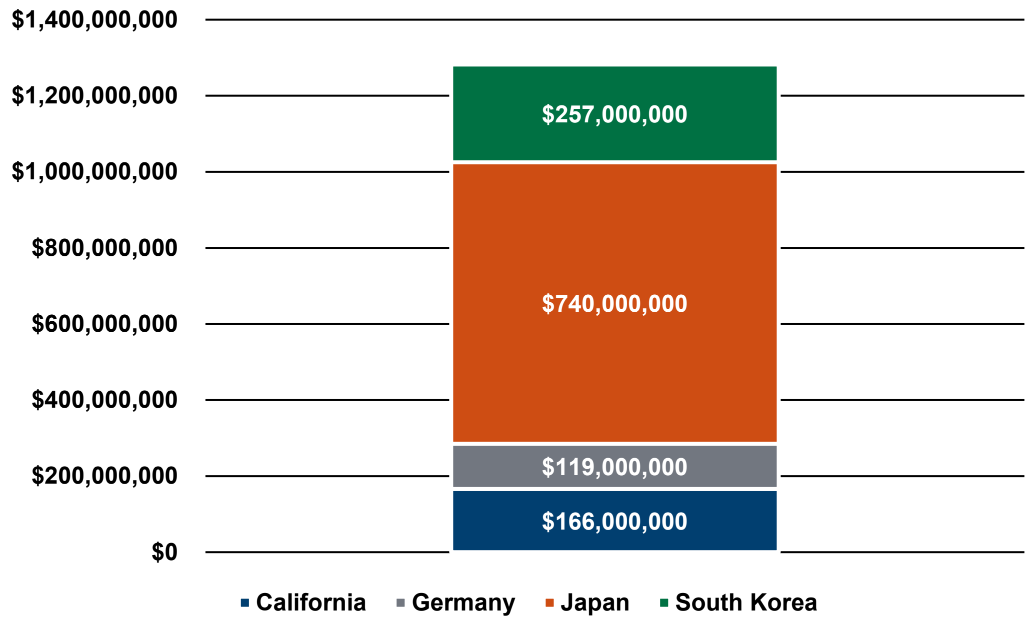
51 CEC staff communicated via email in June 2022 and July 2022 with representatives of national government agencies and organizations in China, Germany, Japan, and the Republic of Korea, as well as the International Council on Clean Transportation (ICCT).

52 The funding amounts were converted in the U.S. dollar using currency conversion rates in July 2022.

53 These additional investments include budgeted funds that are not approved, encumbered, or spent yet.

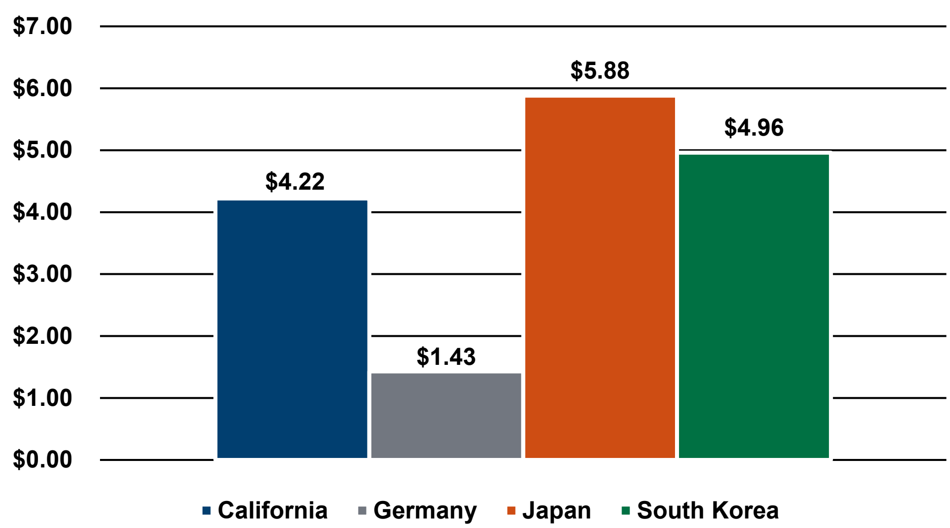
in China deployed 710 hydrogen-powered vehicles to transport athletes, officials, visitors, and reporters during the Winter Olympic Games in February 2022. Stations in Zhangjiakou dispensed 94.3 tons of hydrogen during the 17-day Winter Olympic Games.[54]

Figure 18: Cumulative Hydrogen Refueling Infrastructure Investments Through 2021 by California, Germany, Japan, and South Korea



Source: CEC

Figure 19: Cumulative Investments per Capita Through 2021 by California, Germany, Japan, and South Korea



Source: CEC

54 Wang Hewu, Ouyang Minggao, Li Jianqiu, and Yang Fuyuan. "Hydrogen Fuel Cell Vehicle Technology Roadmap and Progress in China[J]." *Journal of Automotive Safety and Energy*, 2022, 13(2): 211-224.

Combined with private investments, these countries have developed enough stations to serve thousands of vehicles as summarized below. On a per capita basis, California ranks second after South Korea for hydrogen refueling station and vehicle deployments.

Table 7 shows information about hydrogen refueling station development and FCEV deployments in California, China, Germany, Japan, and South Korea. The FCEV numbers for Germany and South Korea are registered vehicles. The responses from China and Japan did not specify whether the numbers are registered vehicles or cumulative sales. The FCEV numbers for California are the estimated on-road light-duty FCEV population and registered buses.

Table 7: Stations and FCEVs in California and Other Countries

	California	China	Germany	Japan	South Korea
Stations	62 open, 113 planned and in development	147 open, an additional 65 built and awaiting a designated operator, 10 under construction, and 8 on pause	96 open and 9 in development	159 open and 15 in development	172 stations built as of March 2022 with a goal to install 138 more stations by the end of 2022
Vehicles	12,169 light-duty FCEVs and 61 buses	8,941 commercial vehicles	1,399 light-duty FCEVs and 107 medium-/heavy-duty vehicles as of June 2022	7,232 light-duty FCEVs and 120 city buses and small trucks in demonstration as of April 2022	20,621 light-duty FCEVs, 152 buses and 5 trucks as of April 2022

Source: CEC

Table 8 shows the comparison between the data received this year and last year on investments, stations, and vehicles. Vehicle numbers represent total number of FCEVs in all classes reported for each country (for example, the 12,169 light-duty FCEVs and 61 buses listed for California in Table 7 sum to 12,230 FCEVs reported in 2022 for California in Table 8).

Table 8: Investments, Stations, and FCEVs in California and Other Countries in 2021 vs. 2022

	$ (million) Invested (reported in 2021)	$ (million) Invested (reported in 2022)	Open Stations (reported in 2021)	Open Stations (reported in 2022)	FCEVs (reported in 2021)	FCEVs (reported in 2022)
California	166	166	52	62	9,701	12,230
China	N/A	N/A	146	147	7,831	8,941
Germany	118	119	92	96	1,325	1,506
Japan	640	740	147	159	5,904	7,352
South Korea	199	257	54	172	15,675	20,778

Source: CEC

To build on the investments they have made, these four countries made goals for stations and FCEVs. Germany, Japan, and China each have a goal of reaching 1,000 stations by 2030.[55] South Korea targets 1,200 stations by 2040. China has established a goal for having 50,000 FCEVs in use as of 2025[56] and it is the world leader in fuel cell truck and bus deployment.

A study recently published by University of California, Davis, looks at international strategies, targets, and policies for creating a global hydrogen economy.[57] The study reviewed hydrogen policy in eight jurisdictions and then narrowed the focus to four: Japan, Germany, South Korea, and California. The study identified achieving GHG emission reduction targets and ensuring economic and energy stability as the main drivers for these jurisdictions to adopt hydrogen strategies. The study also identified different challenges these jurisdictions face in developing the hydrogen system and pointed to the lack of supporting infrastructure, such as that for hydrogen distribution, to meet projected hydrogen demand as a common challenge for all jurisdictions.

55 The goal set by China was obtained from the website of the State Council of the People's Republic of China. "Green Hydrogen to Rise in China." https://english.www.gov.cn/news/topnews/202205/05/content_WS62732b97c6d02e533532a417.html.

56 Center for Strategic and International Studies. February 3, 2022. "China's Hydrogen Industrial Strategy." https://www.csis.org/analysis/chinas-hydrogen-industrial-strategy.

57 Vijayakumar, Vishnu, Lewis Fulton, Mahdi Shams, and Daniel Sperling. 2022. *Creating a Global Hydrogen Economy: Review of International Strategies, Targets, and Policies With a Focus on Japan, Germany, South Korea, and California.* UC Davis: Hydrogen Pathways Program. https://escholarship.org/uc/item/9f95p0m1.

CHAPTER 6: Remaining Cost and Time Required to Establish a Network of 100 and 200 Hydrogen Refueling Stations

This chapter focuses on the remaining cost and time required to establish a network of 100 and 200 hydrogen refueling stations.

The CEC has spent about $166 million to support 86 stations funded by solicitations through the initial batch of GFO-19-602. Staff anticipates awarding another $86 million to fund 82 more stations under GFO-19-602. With the one-time funding from the 2021 Budget Act, the CEC's Clean Transportation Program will have invested nearly $279 million, with the goal to have 200 stations (including 16 stations included in a CEC agreement funded fully by match share and 7 privately funded stations outside CEC agreement) by the end of the program. The funding is subject to future Clean Transportation Program appropriations and Investment Plan allocations and combined with funding from the VW Mitigation Trust Fund.[58]

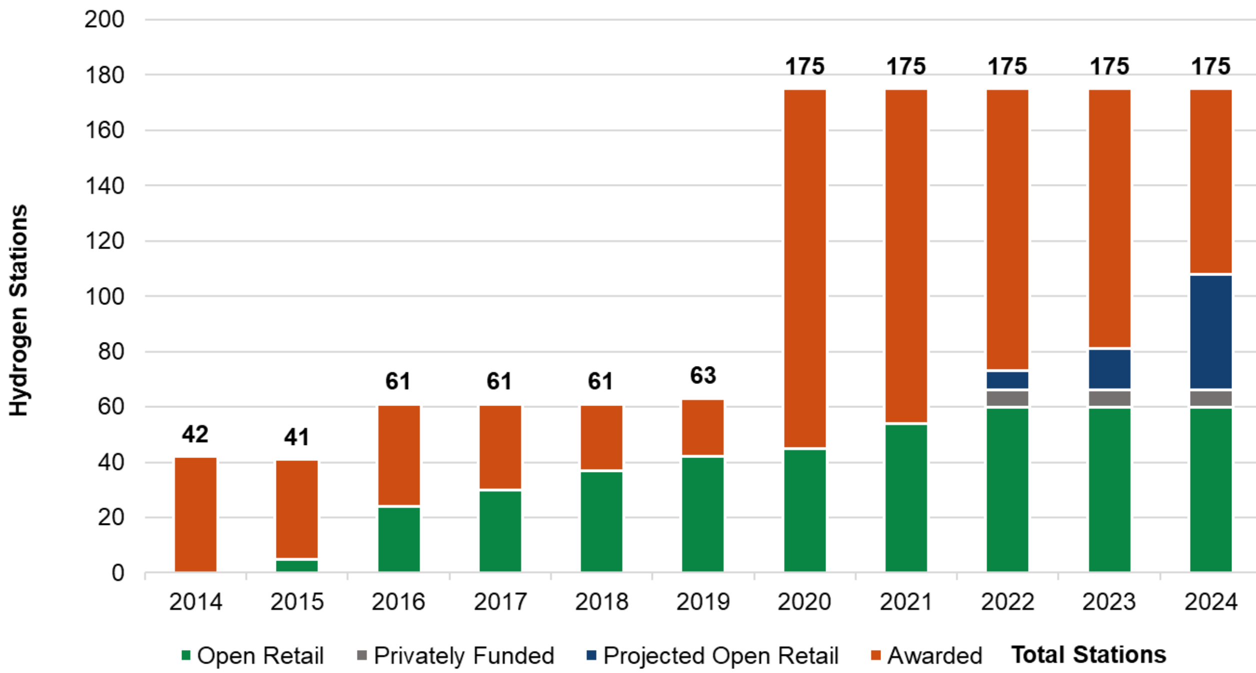
Private investment has included nearly $92 million to match public-sector funding to date, and grant recipients will have committed more than $99 million in additional match funding by the end of the most recent CEC grant agreements, making the total private investment about $191 million. The total reported public and private investment in hydrogen refueling stations is nearly $470 million, although, this figure may be higher because some private sector investment has not been reported.

The stations funded by the combined expended and committed funds will meet and exceed the 100-station goal set by AB 8. In fact, California is well on the way to having nearly 200 stations. The CEC's recently released solicitation, GFO-22-607, for $27 million using general funds from the ZEV infrastructure package of the 2021 Budget Act, will support additional hydrogen stations with the objective of reaching the state's 200-station goal. Figure 20 shows the total estimated stations resulting from the Clean Transportation Program, the VW Mitigation Trust Fund, and private investments. The total estimated stations include 16 stations included in a CEC agreement with FirstElement Fuel funded fully by match share and 7 privately funded stations by Iwatani Corporation of America. Staff estimates the state will have more than 100 stations open retail in 2024, based on the station development schedules shared by station developers.

58 California Air Resources Board. "Volkswagen Environmental Mitigation Trust for California." https://ww2.arb.ca.gov/our-work/programs/volkswagen-environmental-mitigation-trust-california.

Other supportive policies, including the CARB LCFS HRI, contribute to the hydrogen refueling station network. Sixty-eight stations have been approved to generate LCFS credits through the HRI provision.[59]

Figure 20: Quantity of Hydrogen Refueling Stations by Year



Source: CEC

In addition to these expended and committed funds mentioned in this chapter, the 2022 Budget Act allocates an additional $60 million to expand hydrogen refueling infrastructure for three fiscal years starting in 2023. This new funding, pending legislative appropriation, will allow the state to expand access to hydrogen infrastructure, including for medium- and heavy-duty vehicles.

59 California Air Resources Board. "LCFS ZEV Infrastructure Crediting — Approved HRI and FCI Applications." Accessed November 16, 2022. https://ww2.arb.ca.gov/resources/documents/lcfs-zev-infrastructure-crediting.

CHAPTER 7: Conclusions

California is on track to meet the AB 8 goal of having at least 100 publicly available hydrogen refueling stations and the 200-station goal with nearly $279 million invested in hydrogen infrastructure by the end of the AB 8 program. Because of strong public/private partnerships, California is successfully launching a statewide, publicly available hydrogen refueling network. California has 62 hydrogen refueling stations open as of November 11, 2022. These stations have excess fueling capacity that is nearly quadruple today's demand needed by about 12,169 FCEVs in California. The hydrogen station network nameplate fueling capacity of today would also be sufficient to meet the 2025 projected demand of 34,500 FCEVs as reported in CARB's 2022 Annual Evaluation.

The 2028 projected FCEV population of 65,600 is less than a quarter of the 274,000 FCEVs that the anticipated fueling network of 200 stations could support based on the nameplate capacity of the stations, assuming future remaining stations will each have an average of 1,000 kg/day capacity. About 62 percent of California's residents who live in disadvantaged communities are within a 15-minute drive time of an open retail or planned hydrogen station. When the 200-station goal is met, potentially more hydrogen installations will be near or in disadvantaged communities. However, CEC and CARB will continue to explore options to expand hydrogen refueling network benefits to as many disadvantaged communities as possible because rural disadvantaged communities and disadvantaged communities with lower population density tend to be farther than a 15-minute driving distance to any hydrogen refueling station.

Although the network of hydrogen refueling stations in California continues to expand and provide more coverage to FCEV drivers, some barriers, including station and supply reliability, remain. The CEC and sister agencies will continue to find ways to help address these barriers.

For meeting California's decarbonization goals, increasing the renewable content of hydrogen used in vehicles is critical. This effort must be in a transparent manner that does not heavily rely on purchasing biogas credits. The CEC has funded renewable hydrogen production plants, and stakeholders in California are planning investments in renewable hydrogen production. More investment is expected in California with the U.S. DOE's funding program for regional clean hydrogen hubs.

California continues to increase investments in medium- and heavy-duty fuel cell electric vehicles and hydrogen infrastructure. The CEC has invested nearly $40 million in medium- and heavy-duty hydrogen infrastructure. Further, the CEC will invest a large portion of the ZEV infrastructure funding in the 2021 Budget Act and 2022 Budget Act to support electric and hydrogen medium- and heavy-duty vehicle infrastructure. In addition, as many as 13 stations already funded under the light-duty investment will be multipurpose stations to serve medium- or heavy-duty FCEVs.

Along with California, other countries, specifically China, Germany, Japan, and South Korea, continue to invest in hydrogen refueling stations and vehicles. Together, California and these four countries have more than 630 open hydrogen refueling stations, including light-, medium-, and heavy-duty hydrogen refueling stations, and have deployed nearly 40,000 light-duty FCEVs and nearly 9,300 medium- and heavy-duty commercial FCEVs. Cumulative government investment in hydrogen refueling infrastructure through 2021 by California and three of these countries (China excluded) totals nearly $1.3 billion.

Station development time continues to be slower than expected as the world experiences supply chain issues resulting from the COVID-19 pandemic. Labor and materials shortages are also affecting station development. Station developers and CEC staff are working together to find ways to overcome these hurdles.

The CEC and CARB intend to continue evaluating the FCEV market, including opportunities and trends in different transportation market segments and potential use of hydrogen in broader energy system decarbonization.

GLOSSARY

California Hydrogen Infrastructure Tool (CHIT) — a geographical information system-based tool developed using ArcGIS software to assess the spatial distribution of the gaps between the coverage and capacity provided by existing and planned stations and the potential first adopter market for fuel cell electric vehicles.

Disadvantaged community — Defined by Health and Safety Code 39711 as the most burdened census tracts in California. Burden scoring is determined by 20 pollution/health and socioeconomic factors.

Fuel cell electric bus (FCEB) — a zero-emission bus that runs on compressed hydrogen fed into a fuel cell "stack" that produces electricity to power the vehicle.

Fuel cell electric vehicle (FCEV) — a zero-emission vehicle that runs on compressed hydrogen fed into a fuel cell "stack" that produces electricity to power the vehicle.

Greater Los Angeles Area — the counties of Los Angeles, Orange, Riverside, San Bernardino, and Ventura.

Hydrogen Refueling Infrastructure (HRI) credits — Low Carbon Fuel Standard (LCFS) credits that allow eligible hydrogen stations to generate infrastructure credits based on the capacity of the station minus the quantity of dispensed fuel.

Hydrogen Station Capacity Evaluation (HySCapE) model — a tool for verifying the dispensing capacity of a hydrogen refueling station, based on the Chevron profile. CARB uses HySCapE to verify station capacity for the LCFS HRI program, and the CEC used it to verify station capacity under GFO-19-602.

Low Carbon Fuel Standard (LCFS) — Standard developed by CARB to reduce the carbon intensity of transportation fuel used in California.

Nameplate capacity — Rated capacity, nominal capacity, installed capacity, or maximum effect, is the intended full-load sustained output of a hydrogen refueling station.

Sacramento Area — the counties of El Dorado, Placer, Sacramento, Sutter, Yolo, and Yuba.

San Diego Area — the area of San Diego County.

San Francisco Bay Area — the counties of Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Santa Cruz, Solano, and Sonoma.

Temporarily non-operational (TNO) station — a hydrogen refueling station that has previously achieved open retail status but has been unavailable for customer fueling for an extended time for various reasons. A TNO station is expected to become available for customer fueling again in the future.

Zero-emission vehicle (ZEV) — a vehicle that emits no exhaust gas from the onboard source of power.

APPENDIX A:
Hydrogen Refueling Stations in California

Table A-1[60] lists the 62 open retail hydrogen refueling stations (55 stations available for customer fueling and 7 TNO stations), with street address and open retail date. Table A-2 lists the stations in the process of becoming open retail. These lists include both Clean Transportation Program-funded and privately funded stations. Real-time status is available to drivers via the Station Operational Status System, maintained by the Hydrogen Fuel Cell Partnership and accessible at the website, https://m.h2fcp.org.

Table A-1: Open Retail and Temporarily Non-Operational Stations

Station Address (A to Z by city)	Open Retail Date
2618 La Paz Road, Aliso Viejo, CA 92656	6/22/2021
3731 East La Palma Avenue, Anaheim, CA 92806	11/29/2016
14477 Merced Avenue, Baldwin Park, CA 91706	2/7/2022
1250 University Avenue, Berkeley, CA 94702	1/12/2021
800 North Hollywood Way, Burbank, CA 91505	8/20/2022
337 E. Hamilton Avenue, Campbell, CA 95008	5/24/2021
2855 Winchester Boulevard, Campbell, CA 95008	6/9/2016
6141 Greenback Lane, Citrus Heights, CA 95621	12/18/2018
24505 West Dorris Avenue, Coalinga, CA 93210	12/11/2015
605 Contra Costa Boulevard, Concord, CA 94523	5/28/2021
2995 Bristol Street, Costa Mesa, CA 92626	12/29/2021
2050 Harbor Boulevard, Costa Mesa, CA 92627	1/21/2016
21530 Stevens Creek Boulevard, Cupertino, CA 95014	4/6/2022
21865 East Copley Drive, Diamond Bar, CA 91765	8/18/2015
1172 45th Street, Emeryville, CA 94608	11/19/2018
18480 Brookhurst Street, Fountain Valley, CA 92708	7/6/2020
41700 Grimmer Boulevard, Fremont, CA 94538	9/7/2017
391 West A Street, Hayward, CA 94541	4/27/2016
11807 East Carson Street, Hawaiian Gardens, CA 90716	3/21/2022
19172 Jamboree Road, Irvine, CA 92612	11/12/2015
550 Foothill Boulevard, La Cañada Flintridge, CA 91011	1/25/2016
20731 Lake Forest Drive, Lake Forest, CA 92630	3/18/2016
15606 Inglewood Avenue, Lawndale, CA 90260	6/22/2017
3401 Long Beach Boulevard, Long Beach, CA 90807	2/22/2016
10400 Aviation Boulevard, Los Angeles, CA 90045	12/21/2018
5151 State University Drive, Los Angeles, CA 90032	11/20/2019

60 This list does not include a station in West Los Angeles that closed permanently.

Station Address (A to Z by city)	Open Retail Date
5700 Hollywood Boulevard, Los Angeles, CA 90028	11/10/2016
7751 Beverly Boulevard, Los Angeles, CA 90036	5/2/2016
8126 Lincoln Boulevard, Los Angeles, CA 90045	8/18/2016
570 Redwood Highway, Mill Valley, CA 94941	6/16/2016
15544 San Fernando Mission Boulevard, Mission Hills, CA 91345	10/26/2020
830 Leong Drive, Mountain View, CA 94043	2/28/2018
350 Grand Avenue, Oakland, CA 94610	9/20/2019
1850 E. Holt Boulevard, Ontario, CA 91761	4/24/2018
615 South Tustin Street, Orange, CA 92866	3/23/2022
3601 El Camino Real, Palo Alto, CA 94306	12/20/2018
313 West Orangethorpe Avenue, Placentia, CA 92870	5/7/2021
8095 Lincoln Avenue, Riverside, CA 92504	3/8/2017
3510 Fair Oaks Boulevard, Sacramento, CA 95864	5/22/2019
3060 Carmel Valley Road, San Diego, CA 92130	12/2/2016
1201 Harrison Street, San Francisco, CA 94103	12/2/2019
3550 Mission Street, San Francisco, CA 94110	2/14/2020
551 Third Street, San Francisco, CA 94107	11/6/2019
101 Bernal Road, San Jose, CA 95119	6/30/2022
2101 North First Street, San Jose, CA 95131	1/15/2016
3939 Snell Avenue, San Jose, CA 95136	5/27/2022
26572 Junipero Serra Road, San Juan Capistrano, CA 92675	12/23/2015
4475 Norris Canyon Road, San Ramon, CA 94583	7/26/2017
150 South La Cumbre Road, Santa Barbara, CA 93105	4/9/2016
1819 Cloverfield Boulevard, Santa Monica, CA 90404	2/1/2016
12600 Saratoga Avenue, Saratoga, CA 95070	3/14/2016
13980 Seal Beach Boulevard, Seal Beach, CA 90740	10/3/2022
14478 Ventura Boulevard, Sherman Oaks, CA 91423	12/2/2021
1200 Fair Oaks Avenue, South Pasadena, CA 91030	4/10/2017
248 South Airport Boulevard, South San Francisco, CA 94080	2/12/2016
3780 Cahuenga Boulevard, Studio City, CA 91604	4/26/2021
1296 Sunnyvale Saratoga Road, Sunnyvale, CA 94087	2/11/2021
3102 Thousand Oaks Boulevard, Thousand Oaks, CA 91362	3/30/2018
2051 West 190th Street, Torrance, CA 90501	8/18/2017
12105 Donner Pass Road, Truckee, CA 96161	6/17/2016
1515 South River Road, West Sacramento, CA 95691	7/7/2015
5314 Topanga Canyon Road, Woodland Hills, CA 91364	10/5/2016

Source: CEC

Table A-2 lists the locations of stations that are under development. The stations are listed in alphabetical order by city. If the station received Clean Transportation Program funding, the CEC solicitation or contract under which the station received funding is provided.

Table A-2: Stations Under Development

Station Address (A to Z by city)	Solicitation or Contract
102 East Duarte Road, Arcadia, CA 91006	GFO-19-602
17325 Pioneer Boulevard, Artesia, CA 90701	GFO-19-602
1100 North Euclid Street, Anaheim, CA 92801	Privately Funded
6392 Beach Boulevard, Buena Park, CA 90621	GFO-19-602
145 W. Verdugo Avenue, Burbank, CA 91502	600-12-018
2911 Petit Street, Camarillo, CA 93012	GFO-19-602
7170 Avenida Encinas, Carlsbad, CA 92011	GFO-19-602
12610 East End Avenue, Chino, CA 91710	PON-12-606
2600 Pellissier Place, City of Industry, CA 90601	GFO-19-602
616 Paseo Grande, Corona, CA 92882	Privately Funded
3160 Carlson Boulevard, El Cerrito, CA 94530	GFO-19-602
13397 Folsom Boulevard, Folsom, CA 95630	GFO-19-602
16880 Slover Avenue, Fontana, CA 92337	GFO-19-602
47700 Warm Springs Boulevard, Fremont, CA 94539	GFO-19-602
3402 Foothill Boulevard, Glendale, CA 91214	GFO-19-602
13550 South Beach Boulevard, La Mirada, CA 90638	Privately Funded
2589 North Lakewood Boulevard, Long Beach, CA 90815	GFO-19-602
988 North San Antonio Road, Los Altos, CA 94022	GFO-19-602
5164 West Washington Boulevard, Los Angeles, CA 90016	GFO-19-602
666 North Santa Cruz Avenue, Los Gatos, CA 95030	GFO-19-602
705 West Huntington Drive, Monrovia, CA 91016	GFO-19-602
1600 Jamboree Boulevard, Newport Beach, CA 92660	GFO-19-602
5821 Nave Drive, Novato, CA 94949	GFO-19-602
4280 Foothill Boulevard, Oakland, CA 94601	GFO-19-602
2160 South Euclid Avenue, Ontario, CA 91762	GFO-19-602
67 Moraga Way, Orinda, CA 94563	GFO-19-602
290 South Arroyo Parkway, Pasadena, CA 91105	GFO-19-602
475 North Allen Avenue, Pasadena, CA 91106	GFO-19-602
2714 Artesia Boulevard, Redondo Beach, CA 90278	Privately Funded
503 Whipple Avenue, Redwood City, CA 94063	GFO-15-605
3505 Central Avenue, Riverside, CA 92506	GFO-19-602
5551 Martin Luther King Jr. Boulevard, Sacramento, CA 95820	GFO-19-602
1930 South Waterman Avenue, San Bernardino, CA 92408	GFO-19-602

Station Address (A to Z by city)	Solicitation or Contract
11030 Rancho Carmel Drive, San Diego, CA 92128	GFO-19-602
1832 West Washington Street, San Diego, CA 92103	GFO-19-602
5494 Mission Center Road, San Diego, CA 92108	GFO-15-605
510 East Santa Clara Street, San Jose, CA 95112	GFO-19-602
2120 East McFadden Avenue, Santa Ana, CA 92705	Privately Funded
266 College Avenue, Santa Rosa, CA 95401	GFO-19-602
10908 Roscoe Boulevard, Sun Valley, CA 91352	GFO-19-602
24505 Hawthorne Boulevard, Torrance, CA 90505	GFO-19-602
14244 Newport Avenue, Tustin, CA 92780	GFO-19-602
2121 Harbor Boulevard, Ventura, CA 93001	GFO-19-602
17287 Skyline Boulevard, Woodside, CA 94062	PON-13-607

Source: CEC

APPENDIX B: Changes in the Planned Network

Since 2017, the planned network changed due to new funding solicitations, station replacements, stations that did not reach completion, and station closures. Table B-1 shows the changes in the planned network resulting from CEC agreements funded by the Clean Transportation Program and the associated number of FCEVs that could be supported. The 50 stations shown in the first row for 2017 were funded under solicitations and contracts before GFO-15-605 and GFO-19-602.

Table B-1: Changes in the Planned Station Network Since 2017

Year	Reasons for Changes	Number of Stations	Number of FCEVs That Could Be Supported
2017	Clean Transportation Program provided Operations and Maintenance funds to CARB-funded CSULA station (60 kg/day), so the station was added to the collection of Clean Transportation Program-funded stations.	50	13,000
2017	The stations planned for Encinitas (180 kg/day), Foster City (350 kg/day), and Los Altos (350 kg/day) were canceled because of lack of clear path to completion, and they were removed from the list of Clean Transportation Program-funded stations.	47	12,000
2017	Sixteen new stations were approved under GFO-15-605 (5,180 kg/day) and added to the list of Clean Transportation Program-funded stations.	63	20,000
2017	Three HyGen Industries stations (130 kg/day each) were addressed at the October 2017 CEC Business Meeting and removed from the list of Clean Transportation Program-funded stations.	60	19,000
2017	Five additional stations (1,600 kg/day) were proposed for funding under GFO-15-605 and added to the list of Clean Transportation Program-funded stations.	65	21,000

Year	Reasons for Changes	Number of Stations	Number of FCEVs That Could Be Supported
2018	FirstElement upgraded 12 stations from 310 kg/day to 500 kg/day liquid technology (+2,280 kg) and the Air Liquide Anaheim station capacity was adjusted in reporting from 100 kg to 180 kg to reflect more realistic operations.	65	25,000
2018	One of the five additional stations proposed for funding under GFO-15-605 did not move forward (360 kg/day) and was removed from the list of Clean Transportation Program-funded stations.	64	24,000
2019	Mobile refueler project (45 kg/day) and Santa Nella (180 kg/day) station ended without completion and were removed from the list of Clean Transportation Program-funded stations.	62	24,000
2019	Station capacities were updated with the numbers reported to the CARB LCFS Hydrogen Refueling Infrastructure (HRI) credit program.[61]	62	35,000
2020	Two more stations (Concord and Redwood City) were approved for HRI credits and station capacities were updated, each using the numbers reported to the HRI credit program. (+1,400 kg/day)	62	37,000
2020	West Los Angeles station (180 kg/day) closed. The station operator lost lease due to redevelopment plans for the site.	61	36,000
2020	30 new stations were approved at the CEC business meeting in December. One of these stations is an upgrade to the station at Torrance.[62]	90	98,000
2021	The station capacities were adjusted using the latest LCFS HRI approved capacities.	90	101,000

61 California Air Resources Board. "LCFS ZEV Infrastructure Crediting." https://ww3.arb.ca.gov/fuels/lcfs/electricity/zev_infrastructure/zev_infrastructure.htm.

62 The 2020 Joint Report erroneously reported the Torrance upgrade as a new station. However, this error does not affect the total number count of 179 stations.

Year	Reasons for Changes	Number of Stations	Number of FCEVs That Could Be Supported
2022	Rancho Palos Verdes (180 kg/day) and Santa Clarita (180 kg/day) stations were canceled due to sites becoming unviable.	88	100,000
2022	Culver City (1,616 kg/day) station was canceled due to issues in obtaining site control.	87	98,000
2022	Seven GFO-15-605 station capacities were adjusted from 1,616 kg per day to 1,212 kg/day due to an error in last year's reporting of the number of fueling positions each station contained.	87	94,000
2022	Seven privately funded Iwatani stations that are outside CEC agreement were added to the total planned station count.	94	102,000
2022	Laguna Beach (808 kg/day) station was canceled due to issues in permitting.	93	101,000

Source: CEC

APPENDIX C: References

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